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ENVIRONMENT OF TETRAPOD LIFE IN THE LATE PALEOZOIC OF REGIONS OTHER THAN NORTH AMERICA

By

E. C. CASE

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CONTENTS

PAGE
Introduction ... 3
Chapter I.—Plan of the Work and Limitation of the Problem ... 5
Chapter II.—General Descripton of Permo-carboniferous and Permian Deposits of Central and Western Europe ... 11
Chapter III.—Summary Description of the Various Basins in Germany ... 19
Chapter IV.—Summary Description of the Permian Deposits of Czechoslovakia ... 53
Chapter V.—Summary Description of the Permo-carboniferous and Permian in France and the Southern Border of the Hercynian Chain ... 67
Chapter VI.—Summary Description of the Permo-carboniferous and Permian in Russia ... 100
Chapter VII.—Summary Description of the Permian Beds of Great Britain ... 110
Chapter VIII.—Summary Description of the Permo-carboniferous Deposits in China and Mongolia ... 118
Chapter IX.—Summary Description of the Permo-carboniferous Deposits of India and the East Indies ... 126
Chapter X.—Summary Description of Permian Deposits of Africa ... 141
Chapter XI.—Summary Description of the Permian and Permo-carboniferous Deposits of Australia, New Zealand, and Tasmania ... 168
Chapter XII.—Summary Description of the Permian and Permo-carboniferous Deposits of South America ... 180
Chapter XIII.—Analysis of the Faunas and Environments ... 189

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ENVIRONMENT OF TETRAPOD LIFE IN THE LATE PALEOZOIC OF REGIONS OTHER THAN NORTH AMERICA

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INTRODUCTION

The present paper is one of a series published by the author during a long-continued attempt to understand the tetrapod life of the Permo-carboniferous and Permian Periods in the final stages of the Paleozoic Era and its environmental relations. By the aid of the Carnegie Institution of Washington the author has been enabled to carry on his studies of the morphology of the tetrapod life of the periods in North America and other countries, and to outline the environmental conditions in North America. Continued assistance from the same source permits this attempt to understand the relations of the fauna of North America to the faunas of other lands.

For the help that has been given in this work the author desires to express his thanks to the authorities of the Carnegie Institution, and to many colleagues, too numerous to mention in detail, who have most generously aided in the work.

The difficulties attending any effort to understand such complex relationships are great and will, perhaps, appear to many minds as inherently fatal to its success.

The first and most necessary step in any such attempt, the isolation of an interval of time and the determination of the beds deposited within that interval of time, is beset with peculiar difficulties, but its accomplishment is a primary factor in the problem. The very nature of the animals studied, terrestrial and fresh-water forms, demands the identification and correlation of isolated patches of terrestrial deposits which can, only by the rarest good fortune, be definitely associated with the widespread marine deposits that must always remain the most dependable of the various means for interpreting the passage of geological time. The variable climatic and physiographic differences reflected in the terrestrial beds render the probability of faunistic differences, even in geographically very closely associated areas, very considerable and introduce a further complication of the problem.

To the objections that may be raised to some of the correlations suggested in this paper, the author can answer only by reaffirming the position which he has previously taken—that when confined within reasonable time limits, correlation by conditions of environment is frequently more useable and dependable in understanding the relations of evolving groups than a strict adherence to the traditional and conventional methods of association with marine deposits. This method is especially workable if it is recognized that physiographic changes are necessarily progressive, not only in time but in space, and that climatic changes must accompany any great physiographic change; a necessary result is the alteration of the environment of life. It follows that a fauna, migrating with its environment either in advance or retreat, may be recognized as the original fauna in regions very remote from its place of origin, and in periods geologically younger than that in which it first appeared. It is a primary thesis of this paper that time is not the sole essential element in evolution, but that environment is in part a determining factor in evolution, or, at least, the screen which selects what forms, otherwise initiated, shall survive or perish.

CHAPTER I

PLAN OF WORK AND LIMITATION OF PROBLEM

The study of the evolution of the tetrapod life in the late Paleozoic involves the preliminary solution of several subsidiary problems:

1. The isolation of the time interval involved, or the isolation of the set of environmental conditions which controlled the development of the forms of life considered.
2. The delineation of the geographic areas to be considered.
3. The determination of the effective factors in the environment—organic and inorganic.
4. The determination of the morphology and the relationships of the various units of the faunas considered.

1. The interval of time within which the evolution of the Amphibia and Reptilia, of what is usually considered the Permo-carboniferous and Permian facies, developed can not be sharply delimited in all places, either above or below. The most preliminary study renders it obvious that in some places the line between the Carboniferous and the Permo-carboniferous or Permian is extremely vague or non-existent, and that in other places the line between the Permo-carboniferous or Permian and the beds above is equally vague or non-existent. The stratigraphic limits of the terrestrial deposits within this interval of time are frequently not sharply marked by indicators of either an organic or an inorganic nature, and where such limits are sharply marked they are not consistently at the same level in the conventional geologic time scale. Any attempt to exactly delimit the interval or time within which the stage of evolution to be studied took place is foredoomed to failure; it is only by use of the principle that a given stage of evolution is closely related to a definite set of conditions and that this set of conditions may shift geographically and exist in different areas in different parts of the conventional time scale, that any harmony of plan or continuity of development can be demonstrated. The reality of such persistence and migration of the environment has been defended by the author in other publications.[1] If it can be shown that similar environmental conditions prevailed in different areas within reasonable limits of time, whether they were exactly synchronous or not, and whether they were stationary or in progressive motion either as an advance, or as a series of advances and retreats with a recognizable resultant, the necessary limits for the study of the relation of a widely dispersed fauna to its environment will be established. The existence of such similar conditions must be determined by a study of past events as recorded in the sediments and included fossils.

2. As the faunas to be studied are found in areas of terrestrial sedimentation, or of contemporaneous degradation, it is obvious that the regions of

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[1] Case, E, C. Permo-carboniferous time versus Permo-carboniferous conditions, Journal of Geology, vol. XXVI, pp. 500–506, 1918.

Idem. Carnegie Institution of Washington, Pub. No. 283, pp. 187–193, 1919, marine sedimentation need be considered only in so far as they aid in the delineation of the terrestrial areas, in so far as they may have influenced the movements of the animals and indicate the effect of adjacent oceans upon the climate, and in so far as they may serve as a check upon the determination of the age of the terrestrial beds. At best, our knowledge of the compass of many of the areas of terrestrial sedimentation is so limited that some considerable portion of the geographical boundaries must be left to inference from a study of the tectonics of the earth's crust and the inherent probabilities of the distribution of land and water.

3. The problem of the restoration of the environmental conditions is solvable or, at least, attackable by the conventional methods of study of the sediments and the contained fossils. Suggestions of such methods have been given by the author in the first chapter of Publication No. 283 of the Carnegie Institution of Washington and similar suggestions are finding their way into an increasing number of papers by various authors.

4. The problem of the morphology and relationships of the integral units of the fauna has been in large part solved by the long series of investigations upon the structure of the animals which have been in progress for many years, at least this portion of the work is so far advanced that it is possible to discuss with some profit the relation of the animals to their environment. Multifarious attempts have been made to establish the taxonomic relationships of the animals upon purely morphological grounds. In this paper an attempt will be made to test the value of a consideration of the life histories of the animals and their relation to their environment as aids to an understanding of their genetic relationship.

It may be necessary at this point, for the clarification of some minds, to state that the author is making no attempt to argue in favor of the causative effect of the environment upon the inception of evolutionary changes. While the author is convinced of the reality of such a causative effect, as contributary, at least, to the inception of morphological evolutionary changes, it is sufficient for the purposes of this study to recognize that change in the environment has invariably preceded evolutionary changes in morphology, that periods of rapid environmental change have been periods of rapid morphological change, and that whether environmental change has been the cause of evolutionary morphological change or has acted as a selective factor in the persistence of strains otherwise initiated, the end result is the same. A knowledge of the conditions under which a group has developed may have an important bearing in the determination of the genetic relationships of the group.

The problem of the attempt to isolate the interval of time, or of sedimentation, to be considered might be attacked by various methods:

It might be by the selection of a peculiar group of air-breathing vertebrates and fixing the limits at the first and last appearance of these forms. This method has been repeatedly applied but has met with uniform lack of success as the group of animals, so striking in their general assemblage of characters, is known to shade into forms of the Carboniferous below, especially in the Northern Hemisphere, and into forms of the Triassic above, especially in the Southern Hemisphere. Such a gradation is the natural and expected thing unless some factor, or factors, of the environment enforced a migration, a complete or nearly complete extermination, or induced conditions which were extremely unfavorable for the preservation of the remains of the animals. Any change in the inorganic environment which could produce so profound an effect would have left some record in the sediments containing the fossils.

The isolation of the interval might be accomplished by the study of the aquatic vertebrates, fishes and aquatic air-breathers, any or all of which in their direct association with the matrix in which the remains are embedded would record any change in the water (as increased or decreased salinity, alteration of temperature, amount of suspended matter or of food supply). Such methods have succeeded in fixing definite points within the time interval but have failed to determine terminal limits over any considerable area.

The attempt might be made by a consideration of the diastrophic and climatic changes recorded in the sediments. In testing such a method it becomes speedily obvious that the intervals so isolated do not correspond with the ones suggested by the conventional time scales. Animals of a similar stage of evolution and of close relationship are not placed in synchronous deposits by such a method, even within the limits of the present continent of Europe.

There remains the possibility of recognizing the shifting of the fauna from place to place and from time interval to time interval as the conditions demanded. By the shifting of the fauna may be understood actual migration or depression in one region and exuberance in another through time.

The separation of the Permo-carboniferous or Permian beds from the Carboniferous beds by any of the criteria suggested above is exceedingly difficult in many places on the European continent, and the results are not satisfactory. For this reason the interval or time of sedimentation considered is longer and much less definitely delimited than is desirable. Even the evidence furnished by the fossil flora, which might be considered as definitive within limited regions, is unsatisfactory. As Sterzel (1886) remarks, "geographical varieties, races, and even species are clearly evident in different areas and the distinction is increased with distance." Also, as Sterzel, Schuster, and Potonié have insisted, the Permian flora is but an impoverished Carboniferous flora, with the introduction of a few new forms. It is obvious that in basins with different histories of sedimentation, diastrophism and degradation a greater or less proportion of the Carboniferous flora would persist into the Permian, in some places more abundantly and longer than in others, and that the distinctive Permian flora would appear with equal irregularity. The same may be said of the fauna. It would be idle to search for a hard and fast criterion for the separation of the beds, strictly applicable without change to all areas, and to force such an agreement by concessions, omissions and twisting interpretations of the facts to suit the hypothesis.

Sterzel has assumed as a working hypothesis that whenever *Callipteris conferta* and *Walchia piniformis* occur in a bed the age is Permian, but that they need not necessarily be present; moreover he recognizes that a Permian flora with *Callipteris* and *Walchia* occur in beds in France which by every other criterion are upper Carboniferous. Gothan (1923, page 63) says all species (of *Callipteris*) are absolutely certain (unbedingte zuverlässige) key fossils for the Rothliegende. No species has ever been found in an unquestionably Carboniferous bed. This statement probably refers to German deposits only.

It is apparent that the time interval in which the tetrapod life of the late Paleozoic developed was a transitional period and that it must be treated as such. Fortunately there is, in many places, a distinct unconformity between the upper Carboniferous and the lowest Permian, and in some places the line between the Middle and Upper Rothliegende is marked by an abundance of melaphyr and porphyry. These two diastrophic features, together with the deposits of the Zechstein Sea, must serve for the fixation of approximate limits. Above the Kupferschiefer practically none of the characteristic forms appear in the Permian of Europe; the lower border is crossed more frequently by representatives of both the fauna and the flora.

In England, Russia and other portions of the Northern Hemisphere the problem is not unlike that of Central Europe. Conditions were so similar that the fauna of North America migrated sparingly (at least the recovered remains are few) into Europe and possibly penetrated even to the slopes of the Ural Mountains. In the Southern Hemisphere, and especially in South Africa where the fauna and conditions are best known, the situation was very different. Instead of the isolated basins and directing mountain ranges there was a vast extent of territory uninterrupted by any dominant physiographic features. Here the animals developed as a distinctive fauna, which finally found its way into Russia and even as far as Scotland. The route of this migration is uncertain; a possible route by way of Madagascar and India is suggested by the existence of a few recovered remains from those places. Huene has suggested a route by way of Northern Africa and the Iberian Peninsula, largely based upon the inferred distribution of land and water at the time. This question will be discussed in a later part of the paper.

The fact that no member of the Permian tetrapod fauna has been found in Australia is most striking and significant. The existence of Australia as a part of the time-honored Gondwana land is not borne out by the evidence of fossil vertebrates; the evidence for such a connection rests upon the presence of the *Glossopteris* flora in South Africa and Australia, and the common presence of a few invertebrates—a shrimp-like fresh-water crustacean, *Phreatoicus*, in the rain pools on Table Mountain, Cape Province, South Africa, and in Australia and Tasmania; the common presence of the Phreodrillidæ, worms intermediate between the terrestrial and aquatic Oligochets; the common presence of *Peripatus*; the common presence of *Galaxias*.[1]

Terrestrial sediments carrying the tetrapod fauna of the Old World occur in the Northern Hemisphere in England and Scotland, Germany, France, Czechoslovakia, Moravia and Russia; similar deposits, but devoid of vertebrate fossils, occur in Italy, the Maritime Alps, Morocco, Spain and Portugal, and on the borders of old Angara Land in western Asia. It will not be an unexpected thing if fossil remains of vertebrates are discovered in these regions. Already we have the reported presence of *Dicynodon* from Laos, Indo-China (Mansuy, 1912), in beds of uppermost Permian, or Triassic age.

Numerous attempts have been made by various authors to delineate the geography of the late Paleozoic. The history of these attempts has been reviewed by Arldt in the first volume of his *Paleogeographie* (1923). A consideration of the various maps reveals a similarity in all the major features but with many minor variations; no single map can show all the phases of the distribution of land and water in the Permo-carboniferous and Permian times but the study on any one of the many published will serve as a point of departure for the discussion of the areas and faunas described in the following pages.

In the following pages summary descriptions are given of the more important and illustrative areas, with an attempt at a census of the fauna and flora of each. The accompanying table gives a general correlation of the terrestrial beds in the different parts of the world. The author believes that this general table will be acceptable to most workers; in matters of greater detail there will be some difference of opinion, some perhaps of considerable magnitude. The maps accompanying the summary descriptions of different areas have been intentionally skeletonized. The author has spent many hours searching detailed maps for obscure localities mentioned in literature, and believes that the presentation of only the localities discussed will save much time to the reader. These localities can easily be oriented by comparing the maps here presented with more detailed ones.

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[1] In this connection see the Presidential Address of Doctor C. Anderson to the Royal Society of New South Wales, May 6, 1925; Journal and Proceedings of the Society, vol. LIX, page 23.

Germany.	France.	Czechoslovakia.	Russia.	England.	Scotland.	Alps and Italy.	South America.	South Africa.	Australia, Tasmania.	China.	India.	United States.
Zechstein.	Thuringian.		Zechstein.	Magnesian limestone and Marl slate.							Upper Permian.	Double Mountain.
Upper Rothliegende.	Saxonian	Lihn.	Kungur.	Lower Red beds.	Elgin.	Verrucano.	Passa Dois.	Lower Beaufort.	Terrestrial (coal) and marine.			Clear Fork.
Middle Rothliegende (Lebach).								Karroo.		Anthracolitic	Damuda.	
Lower Rothliegende (Cuseler).	Autunian.	Schlan.	Artinskian.				Tubarão. Orleans conglomerate.	Ecca. Dwyka tillite.	Glacial.		Lower Permian. Talchir.	Wichita (Albany) Carboniferous.
Ottweiler (Saar beds)	Stephanian.		Uralian.	Carboniferous.	Carboniferous.							

CHAPTER II

GENERAL DESCRIPTION OF PERMO-CARBONIFEROUS AND PERMIAN DEPOSITS OF CENTRAL AND WESTERN EUROPE

It has been shown that the continent of Europe as a whole may be divided into several areas on the basis of the character of the deposits:

1. Western Europe, including Great Britain, France, and Germany. Deposits terrestrial in character.
2. Eastern Europe. Deposits marine and terrestrial in character.
3. The Mediterranean region and its extensions. Deposits dominantly marine in character.

Such a geographical division, however, scarcely makes apparent the conditions under which sedimentation took place and the life of the time developed. Such things will be more apparent if the areas of sedimentation are considered under the following divisions:

1. The deposits of the northern border of the Hercynian uplift. Terrestrial in character; pre-Zechstein time.
2. The intermontane deposits of the Armorican and Variscan chains. Terrestrial in character.
3. The deposits of the southern border of the Hercynian uplift. Largely terrestrial but shading into—
4. The deposits of the southern and eastern side of the uplift, which are dominantly marine.

To understand these divisions it is necessary to understand the mountain-making movements of the time, and the accentuation of earlier movements. Elevation and re-elevation began in the upper Carboniferous and divided Europe into northern and southern basins or aggrading areas. The continued growth of the Armorican and Variscan chains accentuated these basins and developed the numerous intermontane basins.

The northern basin, with its coal fields of Carboniferous age, became an area of terrestrial sedimentation with the common history of increasing aridity of climate, broken only by the short-lived invasion of the Zechstein Sea. This is the eastern extension of the uplift described by Jukes-Brown (1922) as affecting England in the closing stages of the Paleozoic.

The southern basin was largely occupied by marine waters, but the southern and eastern borders of the Variscan chain furnished a large mass of sediment which was "in part forming alluvial fans above sea-level, though the margins of these fans extended into the sea." (Grabau, 1921.) The content of these fans is the red shales and conglomerates of Switzerland, Hungary and Italy, the "Verrucano" and its equivalents. From the eastern and southeastern slopes of the Armorican chain came the terrestrial sediments of France, Spain and Portugal; these are interrupted by the marine deposit of the westward extension of the Mediterranean Tethys over the region now occupied by the Pyrenees.

At the same time terrestrial material was accumulating in the deep (Born, 1921) intermontane valleys of the chains themselves, and on the eastern and northeastern slopes of the Variscan chain. The deposits of the divisions 1, 2, and 3 must be in most respects similar, but those of 1 shade into the deposits of a flat land or an inland sea, and those of 3 shade into the true marine sediments of 4.

In considering the position and character of the deposits in these areas it must always be remembered that there were two periods of considerable disturbance in Europe near the close of the Paleozoic. The first and most widespread, responsible for the unconformity between the Upper Carboniferous and the Rothliegende, and the lower beds, is commonly referred to as the Hercynian movement. The second, responsible for the less common unconformity between the Lower and the Upper Rothliegende and extending its influence even to the Zechstein, is called by Walther (1923) the Franconian movement. Accompanying both of these movements there were abundant volcanic disturbances with extrusion of much material. Hennig (1923) has called attention to the fact that the folding and attendant vulcanism was progressive from south to north in Germany as well as in central France, which accounts for much of the confusion in stratigraphic determinations.

These movements appear to be but a part of a world-wide movement which has left its record in a disturbance of previously folded regions in northern Europe, southern and eastern Russia, central and eastern Asia, Japan, Sumatra (?), South Africa, and North America. With the second movement and outbreak the disturbance declined and a period of comparative quiet ensued. Concerning this second movement, R. C. Chamberlin (1914) says—

> "It is not sufficiently recognized by geologists that the diastrophism marking the closing stages of the Paleozoic was a double diastrophism comprising an essentially world-wide Hercynian orogenic disturbance—the Westphalo-Carbonide movement between the Westphalian and the Stephanian—and a more local Appalachian disturbance, the Permo-Carbonide movement, after a portion, at least, of the Permian. It was the earlier, or Westphalo-Carbonide, movement that inaugurated those profound climatic changes which are recorded in the astonishing wide prevalence of Red Beds the world over, and which are reflected in turn in great changes in life, and which in view of the dominating character of these changes and the great significance from many standpoints, may perhaps not unfittingly be chosen as the dividing line between the Paleozoic and the Mesozoic."

After the first folding came the great outbreak of volcanic activity with flows of lava covering large areas. At the time of the younger folding came the flows of Leipzig, Halle, Waldenburg, Erzgebirge, in Thuringia, in the Saar region, in the Vosges, the Schwartzwald, at Bötzen, Lugano, and in the Central Plateau of France. The uppermost layers of the Rothliegende are frequently almost entirely made up of superimposed lava flows and frequently water-laid volcanic ash and other ejecta.

Haug, in his *Traité de Géologie* (page 827), gives the following picture, freely translated, of the sequence of events which preceded and led up to the development of the structures and topography upon which were laid down the terrestrial deposits in Permo-carboniferous and Permian time. The general relations of the folds are shown in figure 1.

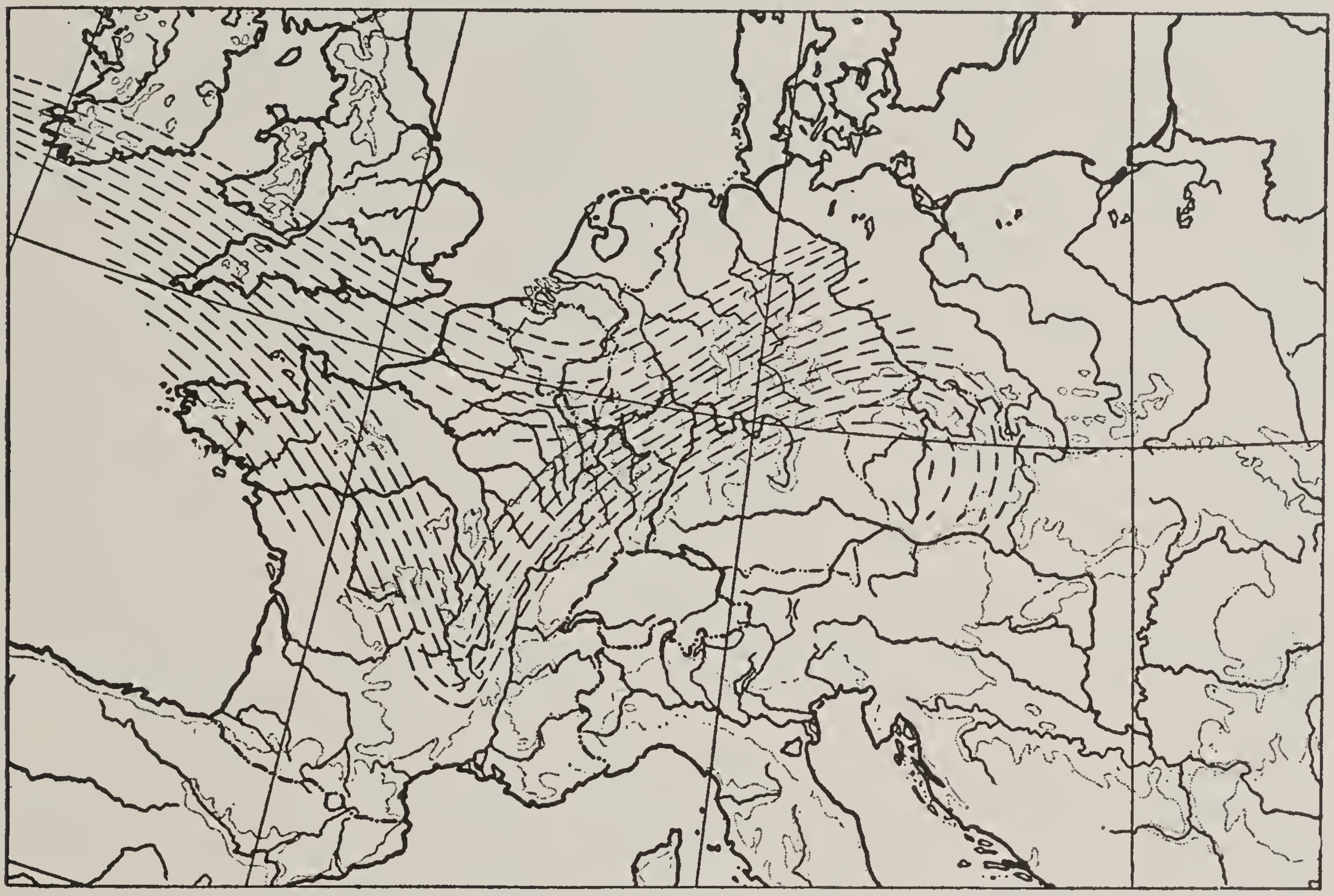

FIG. 1.—Sketch map showing position and direction of Armorican and Varsican chains in central and western Europe.

"There were no movements between the Carboniferous and the Devonian in western Europe, for the Lower Carboniferous is conformable upon the Devonian and the Middle Carboniferous is conformable upon the Lower Carboniferous; but the whole area became a region of depression in the time of the Hercynian folds (the Westphalo-Carbonide movement of R. C. Chamberlin) with the axes of the synclines parallel to the folds and sinking by sudden stages. These depressions were filled by the débris of plants and by detrital matter until they became swamps situated upon the border of the sea. This permits an understanding of the alternate swamp and sea deposits and the autocthonous and allocthonous coal. Shortly after the Stephanian the whole area was raised but the area of folding was localized on the southern border of the western zone in the Franco-Belgian coal fields and their extensions east and west. The northern part was thrown into low, broad folds only. In Wales these folds are at an angle of 45 degrees to the older folds, but in the Ardennes not enough is known to distinguish whether two sets exist. The folds extend south to the Mediterranean and few regions escaped the effect. Two dominant directions are recognizable, one northwest-southeast, the Armorican chain, and the other southwest-northeast, the Variscan chain; together the two form the Hercynian uplift. The two chains meet in a sharp angle in the Central Plateau of France but come together in a gentle curve in the Ardennes with the opening to the north. The Variscan

> chain conforms to the Bohemian Mass and on the east extremity the folds run north-south in Moravia and the Carpathians; the Tertiary movements of the Alps completely mask any extension of the folds into the Balkans and the Dobrudja.
>
> "The elevation attendant upon the Hercynian movement resulted in very rapid erosion which poured great quantities of coarse débris into the over-deepened valleys; localities where quiet deposition took place in the early Permian are rather the exception."

Huene (1925[1]) gives a picture of the situation, largely drawn from Born, which is, freely translated, as follows:

> "At the beginning of the Upper Carboniferous there were already depressions (lochartige Senken, Born) in existence, these were the Saar region, the Saal depression, the Middle German depression, and the Middle Bohemian depression. These began in the time of the Waldenburg and the Saarbruck stages. In Ottweiler time and in Cuseler (lower Permian) these basins grew in the direction of their long axis (parallel to the Hercynian lines). Slowly the filling of several of the basins united the originally separate areas, as for instance, the Saal depression with the North Suedetic depression by Lebach time. By Upper Rothliegende the sediment of the Variscan Intermontane Basins of the Middle German depression reached its greatest extent, reaching from the Saar region to Silesia; the Middle Bohemian Basins developed in a similar manner. By this time the basins had lost their original form and orientation (parallel to the folds), the sediments extended laterally far beyond the original boundaries, covering the degraded barriers and forming a flat surface over the old highlands. With the accomplishment of this leveling a small sinking was sufficient to permit the North Russian sea from the eastern Arctic region to send a relatively small arm over middle Germany and even to north England in Upper Permian time. Soon this sea was cut off in north Russia, converted into a mediterranean in Zechstein time, and desiccated with the deposition of salt and gypsum."

Born has shown that the original basins were over-deepened by the folding movements and that their bottoms lay below sea-level; the load of sediment increased the sinking until thousands of feet (7,000 meters in the Saar region) of Carboniferous and Permian deposits accumulated. The folded areas have been much faulted but the faulting was not synchronous with the folding or even broadly contemporaneous with it in all places. In the northern portion the faulting took place "long after" the beginning of the depression of the coal beds and their accompanying sediments and was in late Carboniferous or Permo-carboniferous time (*Lethea Geognostica*, page 405). In the southern portion the faulting was apparently more nearly synchronous with the deposition of the barren sandstone and is late Carboniferous or early Permo-carboniferous. In many places the course of the faults, especially the younger ones perhaps associated with the Tertiary folding of the Alps, do not follow the trend lines of the mountain chains. The result is that many areas have been broken and blocks elevated or depressed with a consequent destruction or preservation of the record. The course of the main faults, both Paleozoic and younger, are indicated upon the map accompanying Walther's *Geologie von Deutschland* (1923).

The first of the late Paleozoic movements was responsible for the formation or at least the accentuation of the intermontane basins and the increased heights furnished the material which accumulated as the lower barren sand-

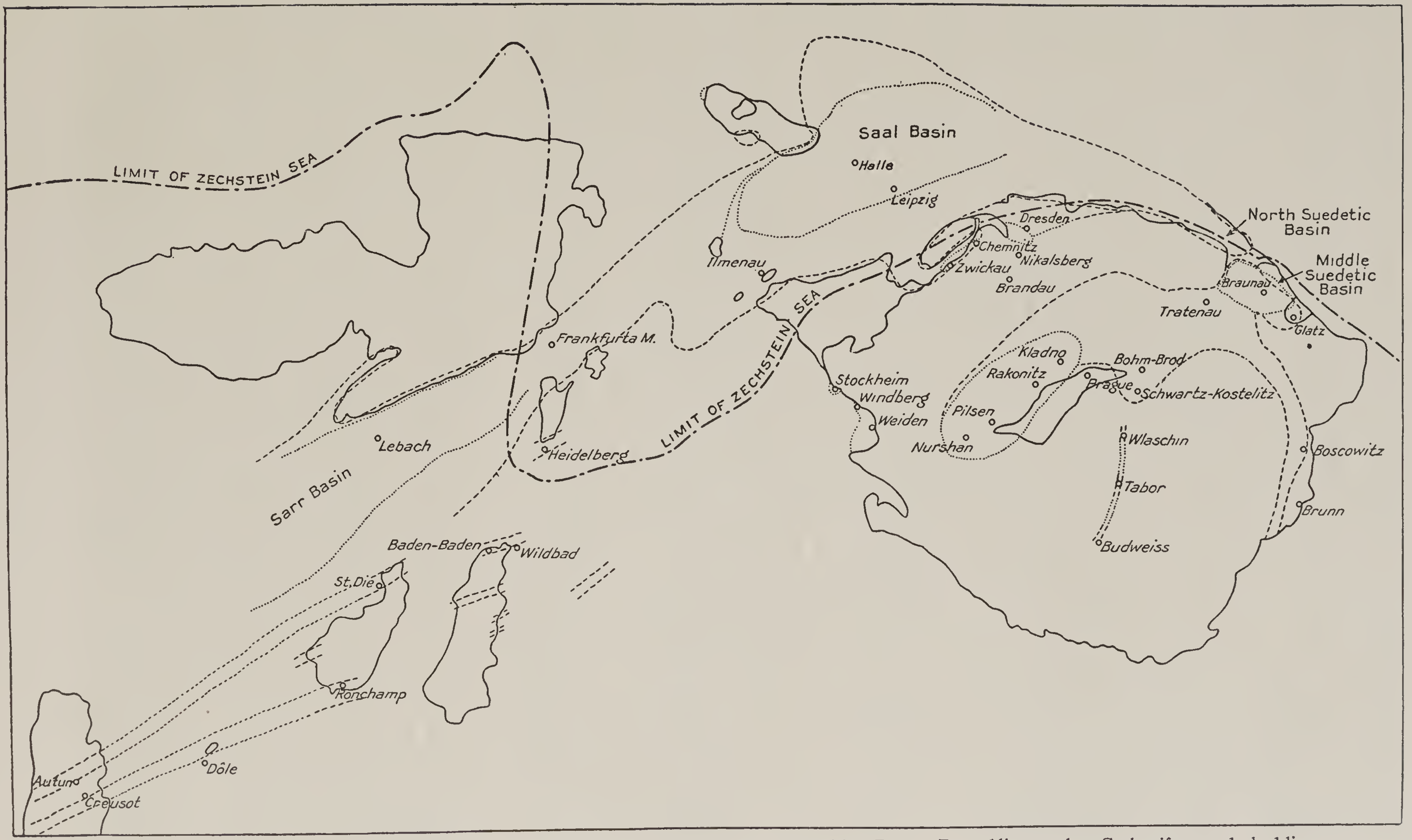

FIG. 2.—Sketch map showing position of various basins in central and western Europe. After Born. Dotted lines enclose Carboniferous; dashed lines enclose Rothliegende; solid lines enclose older Paleozoic and crystallines; dash and dot lines show limit of the Zechstein Sea.

stone (often arkosic or even verging on conglomerate), which is present in the various isolated depressions. The correlation of the deposits in the isolated basins is extremely difficult; the most hopeful attempt has been made by Born (1921) who has attacked the problem on lithological and tectonic ground.

The red, or barren, sandstone found at the base of most series of sediments indicates a decided change in the climatic conditions, which was probably induced by the rise of the peaks and ridges forming barriers to the winds; the sandstones are typically developed in the Waldenburg-Schatzlar, Saarbrucken, and some of the smaller basins. In the damper oceanic climates of England and Upper Silesia the barren layer is completely absent. Also the thickness of the layer records its proximity to the old mountains; in Lower Silesia it is 5,000 meters thick, in Upper Silesia it is from 1,000 to 2,000 meters thick and the material is much finer.

The intermontane basins formed by the folding and obscured by faulting and subsequent erosion are outlined by Born (1921). The more important are the North and Middle Suedetic Basins, the Saal Basin, and the Saar Basin; smaller basins occur in the region of the Schwarzwald, the Vosges, and the Schwabian Jura. It is probable, according to Born, that the series of basins extended southwest into the region of the Central Plateau of France and perhaps northwest again, even into Great Britain.

The bordering areas lie upon the northern and southern slopes of the old ranges and their deposits show, in part, close to the old elevations, and in part in more remote regions, as upon the slopes of the Tertiary Alps in the Maritime Alps of France, in Italy, and on the eastern sides of the southern extension of the Suedetes. It is possible that the deposits of the Czechoslovakian Basins may be more truly bordering deposits than intermontane.

The following free translation of remarks taken from Born's paper and the accompanying map give a more complete idea of the intermontane areas of sedimentation:

> "If one reviews the assembled evidence it is apparent that there were local areas of sedimentation during the old Carboniferous, pit-like basins as the Saar Basin, Saal Basin, Middle Suedetic and Middle Bohemian Basins. These basins expanded somewhat in Ottweiler time and very markedly, in the direction of their major axes, in Cuseler time. This resulted in the formation of elongated areas of sedimentation; the Saar-Maingau-Wetterau, the Thuringian Forest-Saal, the Middle Bohemian-Trattenau-Hohenelbe. The tendency to expansion continued into the Rothliegende until the Saal Basin came into connection with the Middle Suedetic Basin. Though there were repeated breaks in the sedimentation in the different basins the process was a continuing one until the Upper Rothliegende, by which time the basins had reached their greatest extent. The sedimentary filling of the Saar-Saal Basin was peculiar to itself, but gradually this basin was extended until it joined, in all probability, the North Suedetic Basin and there was a single great zone of sedimentation on the inner side of the Variscan Arch, the Saar-Saal-Katzbach, or Middle German Basin. This basin had its parallel upon the Bohemian Massif in the Middle Bohemian Basin of Rothliegende time. The latter basin was originally oriented with the Erzgebirge but in the process of its development the axis swung around, at least

by Upper Rothliegende, probably even by Middle Rothliegende, until it came into connection with the Middle Suedetic Basin and the long axis was oriented parallel to the general Suedetic direction. The great expansion of the sedimenting areas during Upper Rothliegende time completely masked the original control exerted upon the small linear basins. The deposits of Upper Rothliegende time spread far and wide over the previously existing highlands, often in heavy beds. It was comparable to the overflowing of filled water basins.

"One can be tempted to seek in the Central Plateau of France the extension of the Saar basin to the southwest. The Upper Carboniferous-Rothliegende depressions there may, however, be more properly connected with the smaller depressions of the Vosges, the Upper Carboniferous–Rothliegende Basin of Ronchamp in the Vosges with the trough of Creusot across the Permian Island north of Dôle, and the Rothliegende of St. Die with the Upper Carboniferous-Rothliegende of Autun. The extension of the Saar Basin must have already reached much farther northeast, for the axis of the Armorican and Variscan arches extend from the Central Plateau of France to the northeast. It may also be necessary to reckon with a sudden narrowing of the Saar depression to the southwest since with the closer approximation of the folded areas in this region there would be a corresponding lack of space.

"A comparison of these Upper Carboniferous-Rothliegende Basins with the young Paleozoic Basin on the outer borders of the Variscan arches shows characteristic differences. Primarily, their relation to the mountain masses is different; the first group is enclosed within the mountain masses, and is a part of them; they are intermontane, elongate depressions without outlet and extending parallel to the direction of the folds. The second group lies on the outer side of the mass of the Variscan Mountains; such are the areas of northern France, Belgium, Rhenish Westphalia and Upper Silesia. The connecting link between Westphalia and Upper Silesia lies sunken under northern Germany. On the southern side of the Variscan Mountains are similar areas, as the Upper Carboniferous and Verrucano deposits of the Alps and Italy; these are bordering areas of sedimentation which as far as any evidence goes, as of zoning of the deposits, never possessed any great depths; there is the same evidence of quiet water as on the northern side of the Variscan Mountains.

"The different relation to the mountain masses compelled a very different development of the facies in the two groups of basins. The bordering basins were not free from occasional incursions of marine waters; they have the so-called paralic structure. The deposits of the intermontane basins are the deposits of confined basins, they are of limnic structure.

"A further facial difference is shown by the part taken by eruptives; only in the deposits of Upper Carboniferous time can any direct comparison be made, since it is almost entirely deposits of this age which are present in bordering basins, except in Poland. There is no evidence of eruptives in the bordering basins, but such evidence is present in the intermontane basins (Middle Suedetic and Erzgebirge); in these the period of eruption already lies far behind that of Rothliegende time. The lack of Rothliegende deposits in the outer, bordering basins (except in Poland) may be regarded as a highly important characteristic. The difference depends upon the sequence of events in the two areas in the early stages of the Variscan elevation. Powerful orogenic movements, which affected very materially the Carboniferous deposits of Northern France-Belgium and the Rhenish-Westphalian areas, had hardly any effect upon the intermontane basins.[1]"

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[1] In transcribing these remarks by Born the author has translated the word "senke" as basin rather than depression because the catchment areas were formed by upfolding of bordering areas rather than an actual sinking of the aggrading regions.

Grabau has given a general picture of the Permo-carboniferous and Permian in Europe which differs in some respects very materially from those given by other authors. Some of his assumptions, as the direction of the prevailing winds, the origin of the red color, and the character of the fish fauna, will not be accepted as entirely warranted. He says (1921)—

> "It will be remembered that the close of the Carbonic witnessed the pronounced folding of the beds of that system and the addition of these folds to the mountain ranges which divided Europe into a northern and a southern basin. The Armorican chain on the west and the Variscan chain on the east constituted the most pronounced topographic elements of these systems. Even during the Carbonic, as we have seen, the northern basin was distinct and subjected to a gradual emergence by the withdrawal of the sea eastward, while over the emerged region coal swamps came into existence and continental sedimentation prevailed. With the opening of Permian time these continental sediments continued to form, but because of the greater elevation of the bounding mountain chains, which then shut out the moisture-bearing winds, the formation of coal swamps had come to an end, and the climate of this basin became more and more arid. As a result the vegetation finally became very scant, except probably in the higher regions of the mountains and on the windward slopes, where the early coniferous trees flourished and developed new genera and species. The lower slopes of the mountains on the northern or leeward sides, however, probably became barren of vegetation, and there rapid disintegration of the rocks was taking place. This disintegration furnished sands and finer rock material which, remaining exposed for long periods of time, had its disseminated iron thoroughly oxidized by the air which filled the spaces between the particles, there being little or no water to occupy these spaces as in the regions of a moister climate. At infrequent intervals heavy rains in the mountains caused torrents of water to rush down the bare northern slopes, and these washed away much of the disintegrated and thoroughly oxidized material which finally came to rest in the bottom of the mountain-enclosed basin. There this material accumulated as river-laid and sometimes wind-modified deposits of sand and mud of considerable thickness.
>
> "Long after, when these beds were buried by younger deposits and underwent a process of aging within the crust of the earth, their color, at the time of their deposition probably a light yellow or ochery tint, changed to red, as bricks moulded from yellow clay change to red on burning, this process driving off the water originally combined with the iron oxide and changing that oxide to the anhydrous state in which its color is red (hematite). * * *
>
> "The most reasonable explanation (of the Kupferschiefer) seems to be that the muds and copper salts were brought by the rivers from the uplands, and that these regions constituted lagoons and estuaries which had come into existence with the revival of river activity as the climate of the region became moister, probably because of the widespread transgression of the (Zechstein) sea. The fish in all probability were inhabitants of the rivers, and as the first inundation of the salt sea reached this district they were destroyed by millions, not having become as yet adapted to life in the salt water."

CHAPTER III

SUMMARY DESCRIPTION OF THE VARIOUS BASINS IN GERMANY

In describing the Permian and Permo-carboniferous areas of Germany it is convenient to begin at the eastern end of the Variscan chain.

The intermontane basin deposits of the Middle Suedetic Basin (of Born, the Lower Silesian-Czechoslovakian Basin of others) lie in the eastern Suedetes between the Eulengebirge and the Adlersgebirge on the northeast and southwest and the Riesengebirge and the Reihensteingebirge on the northwest and southeast. The area is roughly outlined by the towns Waldenburg, Landeshut, Schatzlar, Hronom north of Nachod, and Glatz.

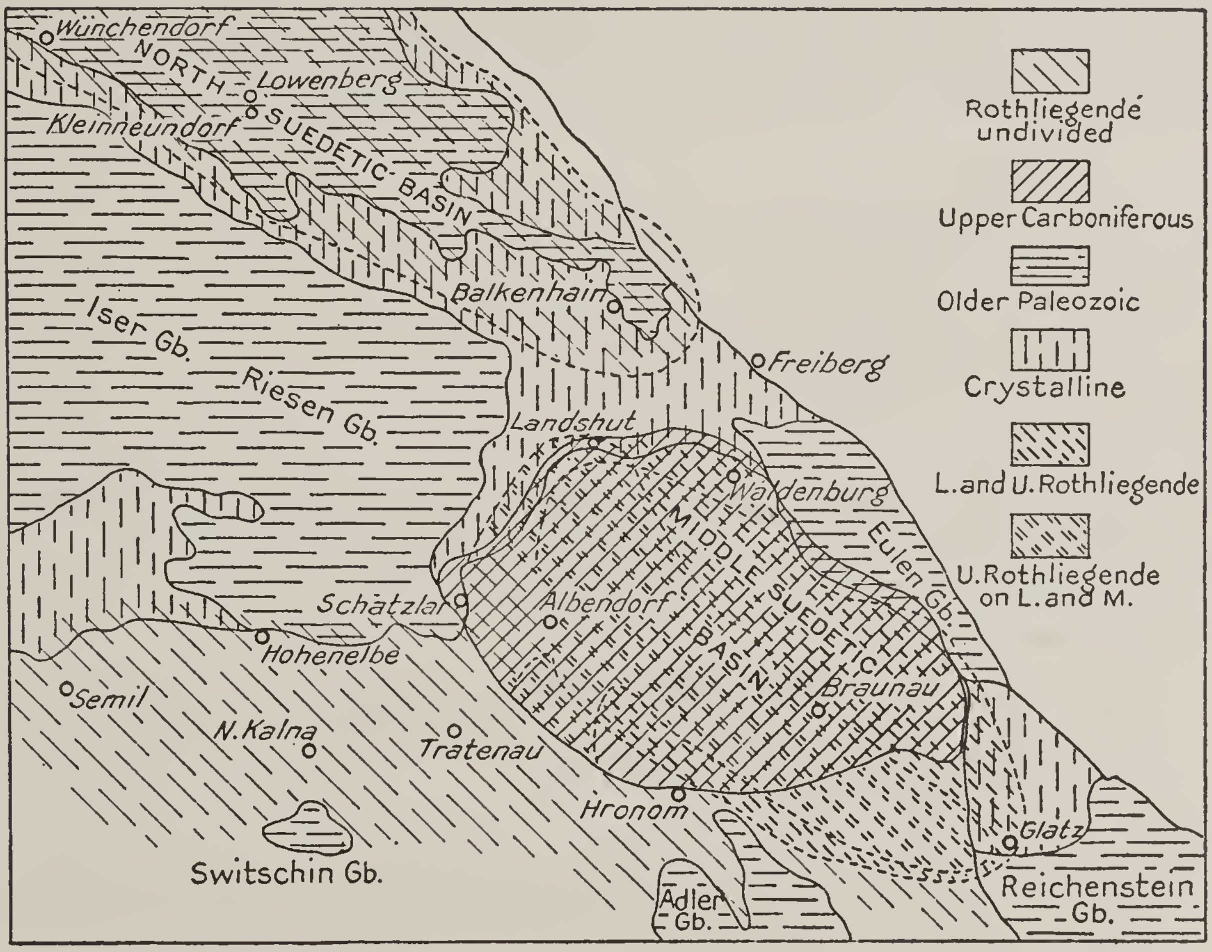

FIG. 3.—Sketch map of Upper and Middle Suedetic Basins. After Born.

This depression received, in late Carboniferous and Rothliegende time, one of the most complete series of deposits of any of the basins. The area was much affected by later movements, as in the Upper Cretaceous, which has rendered the deciphering of the history especially difficult; the original position and extent of the beds can not be exactly determined. The Lower Rothliegende is always conformable on the Upper Carboniferous but is transgressive both to the northeast and southeast. The sedimentation reached its maximum, 2,000 meters, in the southeastern part of the depression in Cuseler time. The coarser material includes many clay and calcareous beds. The fossiliferous shale and limestone diminish in quantity from the northeast portion of the basin toward the northwest portion and are replaced by an increased quantity of conglomerate in which the size of the elements increase in the same direction, indicating the source of the material and the nearest highland. In this region the record is more difficult to read.

With the beginning of the Middle Rothliegende (Lebach) there was great eruptive activity, but this did not prevent continued sedimentation as beds of Lebach age are found both above and below the extrusive sheets.

The conglomerate of the Upper Rothliegende lies unconformable everywhere upon the middle and is transgressive upon older beds. The sedimentation was strongest in the western part of the depression south of Schomberg where the sandstone is very thick and is perhaps continuous with that of the basin at Tratenau. The material of the sandstones and conglomerates is directly derived from the adjacent heights. The general section for the basin is as follows:

Zechstein.
Angular unconformity.
Upper Rothliegende.
Angular unconformity.
Middle Rothliegende (Lebach and Tholier).
Lower Rothliegende (Cuseler).
Ottweiler.

A section from a shaft in the Grafschaft Glatz, quoted from the sixth edition of Kayser's *Lehrbuch d. Geologie*, is as follows:

UPPER ROTHLIEGENDE:

7. Red sandstone and clay shale = Kreuznach beds.
6. Red conglomerate and dolomitic limestone = Wadern beds.
   Break and discordance.

LOWER ROTHLIEGENDE:

5. Red shaly marl, sandstone and limestone. *Estheria*, *Paleoniscus*, and *Callipteris conferta* = Tholier beds.
4. Gray *Walchia* shale and sandstone, limestone. *Callipteris conferta*, *Walchia piniformis*, *Pecopteris*, etc. = Lebach beds.
3. Beds of porphyry, melaphyr, etc., tuff. *Walchia* shale with thin limestone = Lebach beds.
2. Gray and red-brown sandstone and shale with coal seams. *Anthracosia* and *Walchia* shale = Upper Cuseler beds.
1. Porphyry tuff; red sandstone and conglomerate; *Anthracosia* shale (*Walchia imbricata*, *piniformis*, etc.; fish remains; *Anthracosia*); red-brown clayshale, sandstone, and conglomerate (*Walchia imbricata* and reptile remains) = Lower Cuseler beds.

This section may be compared with the following column, which is most commonly accepted as the best statement of the general sequence of the Rothliegende beds in Germany.

- Upper Rothliegende:
  - Kreuznach beds.
  - Wadern beds.
- Middle Rothliegende:
  - Tholier beds.
  - Lebach beds.
- Lower Rothliegende:
  - Cusler beds.
  - Lower Cuseler beds.

By some the middle and lower divisions are united in one, the Lower Rothliegende.

Strigel (1914, page 129) gives the following general summary statement of conditions during the time of the filling of the Middle Suedetic Basin; his summary is largely derived from Dathe's (1904) detailed description of the basin.

In Upper Carboniferous and in Rothliegende time there were laid down alternate masses of conglomerate, sandstone and shale. The Cuseler deposits reach a thickness of 1,000 meters in the center of the basin. In Lebach time deposits were formed near Wünschelberg in a "deep fresh-water lake" (Dathe). Conditions for the formation of coarse sandstone and conglomerate were not present, but there was an increase in the proportion of calcareous material laid down, over that in Cuseler time. These deposits are coarser toward the northwest and finer toward the southeast. On the south side of the basin the overlap of the Rothliegende is obvious.

In his effort to determine recognizable limits for the time interval under discussion, the author has spent much time in an examination of paleobotanical literature. The hope was that a study of the fossil plants might result in the establishment of one or all of the following:

1. Definite geological horizon lines, or time intervals.
2. Different environmental conditions in the different basins, due to different physiographic conditions, or time intervals.
3. A broad change in the ecological conditions either directly and synchronously over the whole area, or progressively, coincident with the unsymmetrical development of the Hercynian system.

Of these it may be said in forecast of the conclusions of this section of the paper that the first was a failure, the second partially successful, and the third partially demonstrable. These matters will be discussed in their proper place. The same results followed an attempt to use the less abundant remains of vertebrate life. It is scarcely becoming in a vertebrate paleontologist to complain of the description and use of *membra disjecta*, but such unfortunate necessity bears harder upon the workers in paleobotany than upon any other group; the short life of certain parts of the plants, the deciduous character of some plants, the great difference in appearance and structure of different parts of the same plant, and the relatively perishable nature of the material, all render it inevitable that dissociated parts of a single plant must be found isolated, and hasty or necessary description of such incomplete material has burdened paleobotany with an excessive amount of synonymy.

Such success as the author may have had in the use of paleobotanical material is due to the kindness of Professor Gothan of Berlin, who prepared for him a long and authoritative list of the plants of the various basins. That the reader unacquainted with the difficulties of this phase of the subject may have some idea of the conditions of the plant world in the late Paleozoic the following description from Potonié (1921) is inserted:

> "The succession of the Rothliegende flora upon the Upper Carboniferous flora is without break. A whole series of species which occur in the uppermost beds of the Carboniferous, as, for example, the Ottweiler of the Saarbrucken area and in even older horizons, pass unchanged into the Rothliegende, as *Pecopteris foeminaeformis*, *P. pluckeneti*, *P. arborescens*, *Sphenophyllum oblongifolium*, *Annularia stellata*, and others, with species of *Calamites* and *Cordaites*. One can therefore consider the Rothliegende flora as a Carboniferous flora. At the same time there is a distinctive character shown by the appearance of new genera and species and by the diminishing or actual disappearance of true Carboniferous forms; it is therefore a dying Carboniferous flora. The most important new forms are the species belonging to *Callipteris* (the best known *Callipteris conferta*), and the first typical conifers, *Walchias*, which according to all that is known, should preferably be associated with the *Araucarites*; also one can indicate the great *Calamites gigas* and others in this connection. Of the Lepidophytes only the *Sigillaria* of the group *Subsigillaria* (*S. brardi*) play a part, while the Rhytidoleps are already as good as gone. The same is true of the Lepidodendrids and the Bothrodendrids. The Sphenophyllales have, in *S. thoni*, the largest species, but find with the *Calamites*, *Cordaites* and *Pteridosperms* their end in this time. *Cordaites* has been reported from younger formations, but the evidence for this is not convincing; the Pteridosperms are represented by many forms (*Neuropteris*, *Alethopteris*, *Linopteris*, *Odontopteris*) but are indicated, so far as yet known, by very few remains from the Zechstein. It is interesting that younger forms, even true Mesozoic forms, are found in the Rothliegende or even earlier horizons; this is true for *Baeria digitata* and related forms, for certain Pterophyllites and for *Ullmannia* forms of the Kupferschiefer.
>
> * * *
>
> Decay
>
> [illegible]
>
> "The species of *Neuropteris* play an important part in the flora of the Rothliegende, the fructification of which shows a relationship to the Marattiaceae; in connection with this are the numerous finds of stems of ferns showing the structure, the Psaronius group, which are associated with the *Neuropteris* and show in the structure a relationship to the Marattiaceae.
>
> "If one would characterize shortly the Carboniferous and Rothliegende flora it might be called the period of maximum development of the group of Pteridophytes."

The following list of the Westphalian and Rothliegende flora of the Middle Suedetic Basin has been furnished by Professor Gothan. The forms occurring only in the Rothliegende are marked by an R.

- Alethopteris costei Zeill.
  - grandini Brgn.
- Callipteridium gigas Gutb. R.
- Callipteris conferta Strnb. R.
  - naumanni Gutb. R.
  - nickelsi Zeill. R.
  - flabellifera Weiss R. (Very rare.)
- Linopteris germari Gieb. R.
- Neuropteris gleichenoides Göpp.
  - planchardi Zeill. R.
  - cordata Brgn.
- Odontopteris subcrenulata Rost.
  - ? minor Brgn.
- Pecopteris arborescens Schlth.
  - oreopteridia Brgn.
  - hemiteloides Brgn.
  - ? candolleana Brgn.
  - unita Brgn.
  - foeminaeformis Schlth.
  - pluckneti Schlth.
- Pecopteris germari Weiss.
  - ? polymorpha Brgn.
- Sphenopteris germanica Weiss R.
- Taeniopteris jejunata Gr. E.
  - multinervis Weiss R.
- Sphenophyllum oblongifolium Germ.
  - ? emarginatum Brgn.
  - majus Bronn.
- Annularia stellata Schlth.
  - sphenophylloides Zenk.
- Asterophyllites equisetiformis Schlth.
- Sigillaria brardi Brgn.
- Cordaites principalis Germ.
- Schutzia anomala Göpp. (? Male infloresecense of Cordaites.)
- Walcha piniformis Schlth.
  - filiciformis Schlth.
  - linearifolia Göpp.
  - flaccida Schimper
- Dictyopthalmus schrollianus Göpp. (Buds of Walchia.)

The following list includes the known vertebrate remains from the Middle Suedetic Basin:

Pisces:
- Acanthodes bronni Ag.
- Amblypterus duvernoyi Ag.
  - voltzi Ag.
- Paleoniscus decheni Gldf.
  - kabalikae Gein.
  - luridus Heckel.
- Pleuracanthus carinatus Fr.
  - decheni Gldf.
- Sagenodus tardus Fr.

Amphibia:
- Branchiosaurus salamandroides Fr.
  - (Chelyderpeton) umbrosus Fr.
- Chelydosaurus vraini Fr.
- Melanerpeton fallax Fr.
  - pulcherimum Fr.
  - pusillum Fr.
- Paleosiren beinerti Gein.

Amphibia—*Cont.*
- Sclerocephalus ? credneri Fr.
  - latirostris Fr.
  - (Osteophorous) roemeri Fr.

Footprints:
- Aciabates sphaerodactylum (Pabst).
- Eumechichnium pachydactylum (Pabst).
  - gampsodactylum (Pabst).
  - v. minor)Pabst).
  - v. gracilis (Pabst).
- Gampsodactylum albendorfense (Pabst).
- Herpetichnium ungulatum (Pabst).
- Ichnium brachydactylum (Pabst.)
- Saurichnites rittlerianus Hocsht.
  - salamandroides Gein.
  - perlatus Fr.

Uncertain:
- ?Datheosaurus macrurus Schroeder.

The region south of the Riesengebirge, roughly outlined by the towns Tratenau, Hohenelbe, Rovensko and Pecka, has generally been associated with the Middle Czechoslovakian (Bohemian) Basin (Born, 1921; Strigel, 1912), but there is little doubt that the Upper Rothliegende deposits extend for some distance east of Tratenau beneath the overlying layers, and are most closely associated with those of the Middle Suedetic Basin. The lower deposits at Tratenau and at Braunau bear a resemblance which indicates that they were laid down under very similar climatic and physiographic conditions. The location of the places discussed in the following pages can best be followed on Blatt 20, Görlitz, in Lepsius's *Geologische Karte d. deutsch. Reichs.*

Frech, in the *Lethea Geognostica*, following the work of Jokely and Porth, gives the following summary statement, somewhat modified here, of the general sequence of the beds.

UPPER, KALNA, BEDS:

Bright red sandy clay shale with subordinate amounts of loose, micaceous, red sandstone and hard arkose. Many layers of marl shale and calcareous shale with beds of siliceous material as jasper, flint, and chalcedony, and clay ironstone and siderite. There are stringers of coal and some copper ore.

MIDDLE, BRAUNAU, BEDS:

Fine-grained, reddish sandstone and micaceous shale; spotted and banded. Sometimes with light greenish flecks or layers of chloritic mica. Occasionally calcareous marl with siliceous material.

Arkose, more or less rich in orthoclase and carrying many silicified stems of plants. Occasionally conglomerate in the deeper portions of the deposits, reddish brown in color. Locally red to snow-white sandstone and dark red to violet, thin-bedded shales. Siliceous material and calcareous marl rare.

LOWER, SEMIL, BEDS:

Gray clay shale with accompanying calcareous marl and combustible shale. At Hoheneck the combustible shale is particularly well developed and contains nodules of clay ironstone and sphaerosiderite in veins and layers.

Green, brown or gray sandstone with some calcareous shale and coal seams.

Gray or brown conglomerate with blocks, up to the size of a human head or larger, of quartz and crystallines; the matrix sandy.

Walther (1923) says that in Carboniferous and Rothliegende time the Suedetes were deeply eroded and the material spread to the east and to the south, aiding in the filling of the main Bohemian Basin; the filling material may be traced from the basin through the bordering deposits toward its source.

A more detailed section of the region in the vicinity of Tratenau is given by Petraschek (1906); it is here given as transcribed by Born:

UPPER PERMIAN:

10. Schomberg beds, Zechstein. The calcareous arkose grades upward into conglomerate with igneous rocks from the south only.

UPPER ROTHLIEGENDE:

9. Zone of calcareous sandstone, transgressing to the south on irregularities of the older rocks.
8. Zone of sandstone.
7. Clay sandstone and clay shale with ripple marks and suncracks.
6. Upper Rothliegende conglomerate.

Unconformity and transgression of Upper beds.

MIDDLE ROTHLIEGENDE:

5. Zone of red clay shale with calcareous layers.
4. Zone of the Hemelsberg conglomerate, dominantly material from the Riesengebirge.
3. Sandstone and arkose with intercalations of calcareous and chalcedonic material and clay shale with *Anthracosia*.
2. Red clay with fish bearing Brandschiefer.
1. Conglomerate.

This section resembles that of the Middle Suedetic Basin in that the lower layers are Brandschiefer, calcareous and *Anthracosia* bearing. The upper part is hardly to be brought, in accordance with even the more westerly part of the same region, in the neighborhood of Starkenbach and Semil. For these places Katzer (1892, page 1189) gives the following:

> Upper or Kalna stage: Red clay shale with sandstone and arkose, occasionally discordant on the older.
>
> Middle stage: Lower part arkose with silicified wood, the upper part sandstone and clay shale. Transgressive on the Semil stage.
>
> Lower or Semil stage: Conglomerate and sandstone, with Brandschiefer, limestone, coal seams, clay ironstone, chert, and copper ore along the borders of the Riesengebirge.

Strigel, in the paper above noted, considers that the middle of these stages is equivalent to the Braunau horizon, a view not shared by Frech, who considers, as shown in the section from the *Lethea Geognostica*, that the Braunau horizon is either not present or is represented by the upper stage. Frech gives the following table, showing the relations of the beds in the region south of the Riesengebirge and in the Middle Suedetic Basin.

Vicinity of Braunau.		South slope of Riesengebirge, Semil, Hohenelbe, Tratenau.
Red marly sandstone of Wünschelberg. No fossils.	U. Rothliegende	Red sandstone and arkose, lignite of Upper Kalna.
Red clay shale and sandstone. Upper conglomerate.		
Red sandstone (footprints at Albendorf) clay shale, lignite of Ottendorf, Niederatkin, etc.	M. Rothliegende. Eruptives and tuff over all.	No break in series. Braunau horizon is not represented by fossil evidence or corresponds to the beds of Upper Kalna.
Reddish limestone or Ruppersdorf and the Ölberg near Braunau. At Dürrkunzendorf, fish, amphibians and plants of Rothliegende age.[1]		Gray sandstone and clay shale. Lignite of Semil near Lomitz, Hohenelbe and Tratenau. The first especially with fish of Rothliegende age.
Lower conglomerate.		
Beds of Kostialov (Lomitz) absent or in any case not represented by fossil evidence.		Conglomerate.

[1] This is the bituminous limestone of Braunau.

Sterzel (1881[1], 1886) says that the beds in Silesia are not true Permian as they carry a Carboniferous flora and are not comparable to the Permian of the Döhlen Basin, near Dresden; the forms found in the middle beds are only comparable, not identical.

The deposits on the south slope of the Riesengebirge, together with those of the adjacent parts of Silesia, lie in an originally continuous depression (compare Born, 1921) with the longest axis approximately east and west in direction. The Lower Semil beds appear as a narrow band, from 1 to 4 km. broad, which can be traced from Starkenbach through Semil, Hohenelbe, Hermannseifen and Freiheid to Tratenau. Locally, as at Hohenelbe, the carbonaceous shale is in sufficient quantity to have been used as a source of illuminating gas and for fertilizer, as the ash contains potash and salts of phosphoric acid. Associated with the shale is the copper ore which was at one time mined for commercial use. The series lies directly upon the crystallines.

The Middle Braunau beds appear in a band similar to the Lower beds and between the residual patches of the Upper Kalna beds. They show transgressive overlap on the Lower beds to the southwest.

The Upper Kalna beds appear as remnants of a formerly much more widely extended mass, which has been broken up and largely removed by the processes of erosion. Detached outcrops are traceable from Kozalov in the east to Tratenau and Eipel in the west. The carbonaceous shale is heavier in the northern part and is much reduced, even absent in places, in the south. In certain places, as north of Rovensko, limestone lenses or layers are present. In many places throughout the area, copper ore is associated with the carbonaceous shale. In some localities the Upper beds lie directly upon the Middle beds but in others they lie upon the Lower beds with evident unconformity.

The carbonaceous shales of both the Upper and Lower beds have yielded fossils and the arkose layers are rich in silicified stems of plants. Tracks of tetrapods are known from Lower Kalna, Branná and Huttendorf, as *Saurichnites salamandroides* Gein. and *Eumekichnium gampsodactylum* (Pabst) (*Saurichnites lacertoides* Gein.), and from Semil, *Saurichnites rittlerianus* Hochst. and *S. perlatus* Fritsch. Abundant remains of fish and plants have been found.

East of Tratenau and Eipel is the area roughly outlined by a line connecting Nachod, Eipel, Tratenau, Schatzlar, Landeshutt, Braunau, and Glatz and divided into two parts by the Cretaceous rocks of the Heuscheuergebirge. The western portion of this area is separated from the area previously described by the depression filled with Cretaceous and Pleistocene material, running from Roth-Kosteletz to Parshnitz, the middle is covered by Cretaceous rocks as mentioned, and the eastern part extends into Silesia where its border lies at the foot of the Eulengebirge. The exposures between Schadowitz and Hronov and those between Roth-Kosteletz and Nachod are only separated by a very thin deposit of Cretaceous; they are apparently continuous beneath this deposit and extend westward until they lie upon the crystallines and thin out until they disappear from the section. Katzer regards these as bordering deposits; as is usual in this region the basal deposits are conglomerates and arkoses, with sandstone and clay shale above. The sandstone and arkose are so rich in fossil stems of plants, some of them 150 cm. in length and free from any evidence of wear due to transportation, that there can be little doubt that this is the site of a former forest.

Between Schadowitz and Schatzlar there are many coal beds, the Radowentz beds, which can be traced from the outcrop of the porphyry at

Albendorf as far south as Hronov; a layer of carbonaceous shale at Potschendorf, northeast of Tratenau, is perhaps of the same horizon and indicates by its contained coprolites, fish scales and plants a close similarity to the "schwarte" of Kuonova.

The eastern side of this area, called the Braunau Basin (Middle Suedetic Basin, *partim*, of Born), is filled with red or reddish-brown, banded or spotted felspathic sandstone and micaceous shale. In this occur two layers of carbonaceous shale and reddish marly, sometimes bituminous, limestone. Near Tranchendorf above Ottendorf in Glatz, at Grossdorf, at Ölberg north of Braunau, and from Heimzendorf to Ruppersdorf the lower of these layers carries fossils. The upper layer is exposed near Wünscheldorf in Glatz. Jokely (*fide* Katzer) considered all the material in the Braunau depression as equal to the deposits between Schadowitz and Radowentz and equal to the Middle and Upper (Braunau and Kalna) beds on the south side of the Riesengebirge, but younger than the lower carbonaceous shale that appears at Semil, Kostialov, Hohenelbe, and Hermannseifen, which has a very similar fauna.

Katzer concludes the fossil forest (which occurs in the lower beds) to be of Permian age and equal in age to the Kuonova horizon; that there is no equivalent in eastern Czechoslovakia of the Nurschan horizon; that the carbonaceous shales of the eastern side of the Riesengebirge, the carbonaceous shale at Kostialov, and Semil, and the red limestone of Braunau are equivalent in age and probably younger than the "schwarte" of Kuonova, but the local differences in the deposits in the isolated, or nearly isolated, basins make the correlation extremely difficult.

Katzer offers the following suggestions in regard to the relation of the Czechoslovakian beds to those of other regions.

Czechoslovakia.	Saxony.	Saar-Rhine.
Semil and Braunau.		
Kuonova.	Döhlen beds near Dresden. Permian of Zwickau.	Lebach.
Nurschan.		
Radnitz.	II to V vegetation zone at Zwickau.	

The flora of this region is very similar to that of the Middle Suedetic Basin; Gothan considers the two regions as one floral community. The fish faunas are the same, but no amphibians have been recovered from the region south of the Riesengebirge. The footprints recorded are—

Saurichnites rittlerianus Hochst.
salamandroides Gein.
perlatus Fr.

It is very possible that some are equivalent to forms redescribed by Nopsca (1923).

Sphenosaurus sternbergi H. v. M. is regarded as a cotylosaur. Its exact locality is unknown, but it is believed to have come from the south side of the Riesengebirge, perhaps from near Semil according to v. Huene.

The North Suedetic Basin lies north of the Riesengebirge and the Isergebirge; the Rothliegende deposits extend practically from Balkenhain to Lauban (see Blatt 20, Görlitz, Lepsius, *Geol. Karte d. deutsch. Reichs*). According to Born this basin was distinct from the Middle Suedetic Basin; he gives the following general section for the whole basin (1921, page 531):

Lower Zechstein. Conformable on lower beds but transgressive.
Upper Rothliegende. Transgressive on lower beds.
Small angular unconformity.
Lebach beds.
? Cuseler beds.
Angular unconformity.
Older Paleozoic.

A more detailed section is given by Scupin (1916) and is here quoted from Born (1921, page 529).

- Upper Rothliegende:
  - Red, sandy, porphyry conglomerate and red sandstone, slightly discordant on older.
- Middle Rothliegende:
  - Upper stage.
    - Tuff.
    - Quartzporphyry sheet.
    - Quartzporphyry tuff.
    - Melaphyr sheet.
  - Lower stage (Lower and Middle Rothliegende of the Preuss. Geolog. Landalt.) Coarse conglomerate, sandstone, shale, and bituminous shale (with a Lebach fauna at Klein-Neundorf). Occasional coal seams and calcareous beds.
  - Unconformity.
  - Old Paleozoic.

The Cuseler stage has not yet been determined paleontologically.

The sediments show decided variations at different localities but retain a general similarity in the sequence of deposition; in general there is a pre-eruptive stage of sedimentation, a period of eruption and a post-eruptive sedimentation.

The following is the floral list for the North Suedetic Basin as given by Gothan; it "contains only Permian flora"—Gothan.

From Wunchendorf:
- Callipteris flabellifera Weiss.
  - naumanni Gutb.
- Odontopteris subcrenulata Rost.
- Pecopteris, type arborescens Brgt.
- P. (Crossotheca) pinnatifidia Gutb.
- Sphenopteris germanica Weiss.
- Schizopteris trichomanoides Goep.
- Calamites sp.

From Wunchendorf—*Cont.*
- Asterophyllites cf. spicatus Gutb.
- Cordaites principalis Germ.
- Schutzia anomola Gein.
- Walchia piniformis.

From Klein-Neundorf:
- Callipteris naumanni Gutb.
- Odontopteris sp.

From Klein-Neundorf—*Cont.*
- Pecopteris, type arborescens Brgt.
- Rhabdocarpus sp.
- Cardiocarpus marginatus H. B. Gein.

From Merzdorf a. Bober:
- Callipteris naumanni Gutb.
  - cf. conferta Brgt.
- Neuropteris cf. auriculata Brgt.

From Merzdorf a. Bober—*Cont.*
- Neuropteris cf. planchardi Zeill.
- Pecopteris ? candolleana Brgt.
- Sphenophyllum oblongifolium Germ.
- Annularia stellata Schlth.
- Equisites ? zeaformis Schlth.
- Cordaites sp.
- Cardiocarpus gutbieri H. B. Gein.
- Walchia piniformis Schlth.

The faunal list for the North Suedetic Basin is very short, but so far as it goes is regarded as indicating Lebach age.

PISCES:
- Acanthodes bronni Ag.
- Amblypterus duvernoyi Ag.
- Pleuracanthus decheni Gldf.

AMPHIBIA:
- Sclerocephalus (Osteophorus) roemeri v. M.

FOOTPRINTS.

INVERTEBRATES:
- Gampsonyx.

The Upper Silesian Basin in the neighborhood of Kattowitz is the easternmost of the isolated coal swamp areas, it lies between Kattowitz, Cracow, and the Beskiden Alps. It is now believed that Permian beds do not occur in the basin but as there are marine layers intercalated between the terrestrial beds, it may be taken with the areas noted in western and central Hungary, as roughly marking the easternmost extension of the European terrestrial area in late Carboniferous and Permian time.

A little southeast of Dresden is the Döhlen Basin celebrated as the source of the material described by Credner. The following section of the basin is given by Credner (1906, page 501) and Kayser (1923, vol. III, page 358).

Middle Rothliegende = Lebach:

5. Capping layer of Hanchen and Wachtelberg porphyry.
4. Quartzporphyry tuff and brecciated tuff. Conglomerate of porphyry and gneiss pebbles, sometimes loose and rubble-like.
3. Abundant light-colored, variegated shale with inclusions of thin sandstone and coarse arkose; some claystone. At Schweindorf a bed of black-striped chert and impure coal. At Niederhässlich two layers of limestone with amphibians, reptiles and plants.

Lower Rothliegende = Cuseler:

2. Conglomerate, sandstone and shale, sometimes gray, sometimes reddish; claystone; three coal seams in the middle, the upper about 5 meters. Many plants.
1. Flow of Postchappel (Wildsrüffer) hornblendeporphyry, locally underlain by tuff.

Krenkel (1915, page 32) gives the following section of the Döhlen Basin:

Middle Rothliegende:

Stage of gneiss-porphyry conglomerate and quartz-porphyry flow.

Stage of sandstone and tuff, breccia.

Stage of variegated shale and marl. Rich fauna in limestone. Coal seams.

Lower Rothliegende:
- Stage of upper gray shale.
- Stage of steinkohl beds, coal, sandstone, and shale.
- Stage of lower gray shale and conglomerate.
- Stage of clay ironstone (13 meters) and Wildsrüffer porphyrite.

Credner (1890) has given a description of the Döhlen Basin from which the following is very closely copied. (See also Beck, 1893; Hause, 1891; Sterzel, 1893.)

The Döhlen Basin is formed by the filling of an originally elongate trough-like depression about 500 meters deep, which extends southeast and northwest parallel to the present Elbe Valley, from the vicinity of Maxen above Postchappel to Wildsrüff. It has a breadth of nearly a mile and length of about 3 miles. The walls of the depression are formed by igneous and metamorphic rocks and the bottom is of older Paleozoics, Cambrian and lower Silurian. The depression was formed and refilled in the latter half of the Paleozoic. The material, which is partly in the form of detritus cones which were extended until their borders met and partly of horizontal beds laid down on the valley floor, is predominantly coarse pebbles, and fragments, gravel, sand, and mud, which later hardened into rock. In the course of the filling, and especially in the first half of the process, there accumulated a considerable mass of plant material which was in part swept off from the slopes of the highlands of syenite to the northeast, which were covered with giant ferns, *Calamites* and *Araucaria*, and partly accumulated in place where an abundant vegetation grew on the swampy floor of the depression. This accumulation of plant material was later converted into the coal which forms the basis of the mining operations at Zauckeroda, Burgk, Hänichen, and Windberg.

During a somewhat later period in the filling of the depression, invading waters with a small calcium carbonate content spread out in broad, flat, stagnant pools; the sediments from these pools formed the thick, sometimes very regular limestones. The waters of the pools abounded in the various forms of amphibian life which have left such a perfect record in the soft and fine-grained calcareous deposit.

Not only the amphibia of the pool but the reptiles which lived upon the banks have left their skeletons in the solidified mud at the bottom of the old stagnant pools.

While these deposits were forming there came the first of the outbreaks of eruptive activity which spread a thick layer of lava over the area, especially in the northwestern part of the depression between Postchappel and Wildsrüff, the Postchappel hornblende porphyrite. The later deposits are much more complex. There is a series of intercalated beds of porphyry tuff, breccia and conglomerate of igneous origin. Most of these are due to more distant eruptions and are either ash and tuff swept into the depression, or disintegrated material which has also swept in. Only at the last when the basin was filled, renewed outflows of porphyry covered the whole area and now crown the heights of the Wachtelberg, east of Tharandt.

A general section of the portion of the beds carrying the limestones is given by Credner. In this part of the series the dominant beds are reddish or light gray shaly marl with two beds of sandstone. Directly below the upper of these lies the upper, or "wild," limestone from 0.3 to 0.5 meters thick; this bed is very irregular, but it is here that the best impressions of the *Branchiosaurus* larvæ are found; remains of adult *Branchiosaurus* and of other genera of amphibia are very scarce. Beneath this limestone there are 5 meters of shaly marl, reddish above and gray below, then a bed of gray sandstone 0.5 meters, 1 meter of shaly marl, and finally the lower bed of limestone. This limestone, despite its slight thickness, scarcely more than a meter, is rather complex. The upper 5 cm. is formed of an impure, sandy limestone with "bread-loaf-like" lenses of dense, splintery limestone; a thin line of marl separates this layer from the next, a dark "stinkstein" scarcely 5 cm. thick; next comes the main limestone, 75 cm. to 1 meter thick, which is separable into four parts. This limestone is gray, fairly dense, with a splintery or conchoidal fracture and often thin-bedded and splitting into plates. The most of the fossils are found in the middle portion of the bed. Only a single skeleton has been found in the marl between the limestones and that is of the reptile *Kadaliosaurus*.

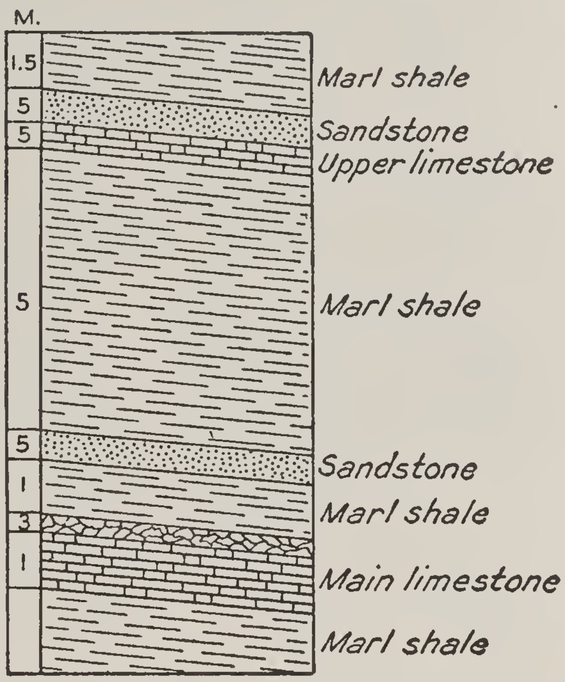

FIG. 4.—General section of Döhlen Basin. After Credner.

Born (1921, page 529) considers that perhaps this basin and the larger depression of the Elbe Valley were continuous with the depression at Weissig where there is a succession of conglomerate, sandstone, tuff, and shale, with two layers of carbonaceous shale carrying *Estheria* and *Anthracosia* of Lebach age. It is not improbable, according to him, that the Elbe Valley depression formed a connection in Middle and Upper Rothliegende time between the great Saal depression and the North Suedetic depression.

Sterzel (1893) comes to the following conclusions concerning the Döhlen Basin:

1. The deposit in the Döhlen Basin forms a continuous not a bipartite series.
2. The flora is equivalent to that in the Erzgebirge and the Mügeln-Frohburg Basins which is equivalent to that of the Lebach beds at Lebach.
3. The fauna of the Döhlen Basin is equivalent to the fauna of the Braunau beds in Bohemia which is equivalent to that of Millery near Autun.

4. The Erzgebirge deposits are paleontologically equivalent to the Middle Rothliegende.
5. No plants are found in the Döhlen Basin that are confined to the Carboniferous.
6. The coal seams carry Permo-carboniferous and true Permian plants.

Sterzel makes several other summary statements which are illuminating as to the age of the Döhlen Basin.

There is no Steinkohle in the Plauenschengrund.

The line between the Rothliegende and the Steinkohle is drawn at the place of appearance of *Callipteris conferta* and *Walchia*, which go together.

Wherever *Callipteris conferta* appears the beds are Rothliegende, but *C. conferta* does not necessarily appear in all Rothliegende beds.

Walchia, especially *Walchia piniformis*, is also a key fossil for the Rothliegende; all reported occurrences in the Carboniferous of Germany and Austria are erroneous. Only in France does *Walchia* occur in the Upper Carboniferous.

Typical of the Carboniferous are ferns, *Sigillaria* and *Lepidodendron*, the Calamites (inclusively), the Sphenophyllums, and as rarities the Cycads and the Conifers. Typical of the Rothliegende are the Calamites, Cordaites, Conifers and Cycads, and as rarities, *Sigillaria* and *Lepidodendron*.

A list of the flora of the Rothliegende from various localities in Saxony, including those of the Döhlen Basin, as given by Gothan, follows:

Callipteridium gigas Gutb.
Callipteris conferta Sternb.
  naumanni Gutb.
  polymorpha Sterzel.
Linopteris germari Gieb.
Neuropteris gleichenoides Göpp.
  planchardi Zeill.
Noeggerathia zamitoides Sterzel.
Odontopteris subcrenulata Rost.
Pecopteris arborescens Brgn.
  candolleana Brgn.
  foeminaeformis Schlth.
  hemiteloides Brgn.
  planitzensis Gutb.
  polymorpha Brgn.
  (Crossotheca) pinnatifidia Gutb.
  similis Gutb. (non Sternb.)
Psaronius zwickavensis Corda.
Sphenopteris burgkensis Sterzel.
  fasciculata Gutb.
  gutzoldi Gutb.

Taeniopteris abnormis Gutb.

Annularia stellata (with Calamites cruciatus Strnb., stem, and Stachannularia tuberculata Strnb., bloom).
Calamites infractus Gutb.
  cf. gigas Brgn.
Calamostachys mira Weiss.

Aphlebia zwickavensis Gutb.
Pterophyllum cotteanum Gutb.
Sphenophyllum oblongifolium Germ.

Cordaites principalis Germ.
Cordaioxylon (Dadoxylon). Silicified stems.
Walchia piniformis Schlth.
  filiciformis Schlth.

Many seeds; the silicified plants remain of Chemnitz and Altendorf, Psaronius (stems of ferns, Zygopteris scandens Sterzel and Asterochlaena laza Sterzel); Cycadofilices (Myeloxylon, Medulossa, Alethopteris, and so forth).

The following is the faunal list of the Döhlen Basin:

From the coal-bearing beds of the Lower Rothliegende:

REPTILIA:
  Pantelosaurus saxonicus Huene.

INVERTEBRATES:
  Anthracosis (Cardinia) tellinaria Gldf.
    (Cardinia) utrata ? Gldf.
  Blattina dresdensis G. and D.

INFUSORIA:
  Chaetophyta saxipara Ehrnb.
    anthracophylax Ehrnb.
    mona β Lithanthracis Ehrnb.
  Trachelomonas laevis ? Ehrnb.
Lamna (?) carbonaria Germar (Balanus carbonaria Petzold).
Spirorbis carbonarius Dawson.

From the Middle Rothliegende:

- Amphibia:
  - Acanthostoma vorax Cred.
  - Archegosaurus decheni Gldf.
    - (Pelosaurus) latirostris Jordan
  - Branchiosaurus (Protriton) amblystomus Cred.
  - Discosaurus permianus Cred
  - Hylonomus (Hyoplesion) geinitzi Cred.
  - Melanerpeton pulcherimum Fr. emend Cred.
    - ? spiniceps Cred.
  - Pelosaurus laticeps Cred.
- Amphibia—Cont.:
  - Sclerocephalus labyrinthicus Gein. emend Cred.
  - ? Sparagmites arciger Cred.
- Reptilia:
  - Kadaliosaurus priscus Cred.
  - Paleohatteria longicaudata Cred.
  - Naosaurus (Edaphosaurus) credneri Jaekel
  - Stephanospondylus pugnax G. and D.
- Invertebrates:
  - Anthracosia stegocephalum Gein.

The Erzgebirge Basin, southwest of Dresden and in the general vicinity of Zwickau and Chemnitz, was in existence, according to Walther (1923), in Carboniferous time and continued as an area of sedimentation throughout the Rothliegende, reaching its maximum extension in Middle Rothliegende time. That the basin was distinct, or developed under different conditions, for a part of the time at least, from the Döhlen Basin is shown by the fact that the bed of workable coal in the latter basin is represented by but a thin layer at Zwickau.

Credner (1906) and Frech (*Lethea Geognostica*) give practically the same section for the Erzgebirge Basin:

- Platten dolomite of the Upper Zechstein.
- Break, with Middle and Lower Zechstein.
- Upper Rothliegende:
  - Tile red clay and conglomerate formed of eruptive material.
  - Eruptive, unfossiliferous.
- Unconformity.
- Middle Rothliegende = Lebach:
  - (b) Brown kaolin sandstone, clay shale and conglomerate.
    - Locally coal seams and calcareous layers.
    - Flows of porphyry and melaphyr.
    - Main layer of silicified *Araucarites*, *Cordaites*, *Medullosa*, *Psaronius*, *Calamodendron*, and other plants.
  - (a) Coarse conglomerate, locally with blocks a meter in diameter from the Erzgebirge and Carboniferous.
    - Layers of porphyry and melaphyr. Silicified *Araucarites* and *Cordaites*. Subordinate layers of quartz sand, clay shale and coal seams; plant remains in the latter.
- Unconformity.
  - Lower Rothliegende lacking.

Sterzel (1893) says that the division of the beds in the Erzgebirge Basin into Lower, Middle and Upper Rothliegende is entirely upon petrographic grounds for cartographic purposes and that paleontologically all the beds belong in the Middle Rothliegende. He considers that the Lower Rothliegende was present but was removed by local erosion before the deposition of the Middle Rothliegende; it has been preserved in Saxony only in the Plauenschengrund. This conclusion is based by him upon both paleontological and stratigraphical evidence (Sterzel, 1918).

Born (1921), quoting from Brandes (1914 and 1919), and Pietzsch (1914), gives the following general section of the same region:

- Upper Rothliegende:
  - Small-pebble conglomerate extending west to the Saal Basin.
  - Unconformity.
- Middle Rothliegende:
  - Tholier lacking.
  - Lebach. Porphyry, quartz-porphyry, and melaphyr alternating with conglomerate and sandstone.
  - Gray basal conglomerate.
  - Unconformity.
- Lower Rothliegende = Cuseler, lacking.

The section at Chemnitz is given by Sterzel (1918) as follows:

Upper Rothliegende.	Lower.	Stage of the marl shale.
Middle Rothliegende.	Upper.	Arkosic sandstone and marl shale. Upper porphyry tuff, sometimes silicified. Arkosic sandstone and marl shale with thin seams of coal, limestone and chert.
	Middle.	Flow of pitchstone quartz porphyry. Lower porphyry tuff with inclusions of sandstone, conglomerate, and marl shale.
	Lower.	Stage of arkosic sandstone and conglomerate with calcareous cement, clay shale, and thin coal seams.

Brandes (1919) gives a section of the Erzgebirge Basin between Zwickau and Chemnitz with some explanation of the succession of events as follows:

Conglomeratic series, practically unbedded and gives the impression of a breccia. 250 meters. (The Kleinstückigen Konglomerat.)

Clay and marl with beds of limestone and dolomite, and salt springs; the upper beds increasingly red in color and of finer grain; the lower beds gray in color.

Porphyry, quartz-porphyry, pitchstone, and melaphyr; beginning 100 meters above the base the flows are intercalated with conglomerate and clay.

Conglomerate, graywacke-like sandstone and arkose, sometimes with a clay cement; near the top small beds and lenses of coal from a few centimeters to a few decimeters thick.

The conglomerate at the base is composed of various igneous rocks now exposed on the north border of the basin in the Granulite Mountains. The boulders range up to 0.5 meter in diameter, those the size of a human head are common and there are some inclusions of clay from below. Interfingering of the conglomerate with the Carboniferous beds indicates that they are perhaps contemporaneous, but sometimes the conglomerate is definitely above the Carboniferous. In places the conglomerate is obviously deposited in gulley-like depressions in the Carboniferous. From the evidence of plants in the overlying beds the conglomerate is of Lebach age. The Ottweiler and the Cuseler are absent.

Brandes believes that the coal material of the Lower Carboniferous beds was swept in from an outside source and deposited in the beds of meandering streams which wound through the depression in Ottweiler and Cuseler time, as footprints and insect remains are found in the same beds. An elevation of the north edge shifted the axis of the depression somewhat to the northwest and furnished the material for the heavy conglomerate at the base of the Rothliegende deposits (see Fig. 5). This depression now contained water as there are beds of limestone and dolomite and there is a calcareous and dolomitic cement in the conglomerate; the volcanic tuff is also waterlaid. The old stream continued to work in the depression with its outlet apparently near Crimmitschau. In the latter part of the Rothliegende there was a desiccation of the climate as there is evidence of "dreikanter" and dune sands, and the absence of plant fossils indicates an over-salinity of the water; the presence of salt springs, the increase in red color, and the unreduced condition of the iron salts are adduced as further evidence of the increasing aridity. The decrease in size of the grain of the beds is attributed to the lowering of the adjacent degrading areas. Brandes considers the coal in the Rothliegende beds as the result of the erosion of beds previously formed and the redeposition of the material.

Brandes summarizes the movements in the Erzgebirge Basin as originating in a faulting during Saarbrucken time. This continued with contemporaneous filling; during Ottweiler-Cuseler time there was a cessation of sinking and a period of erosion by the meandering stream. In Lebach time there was a renewal of the depression by the elevation of the northern border and a shifting of the axis of the depression to the northwest; the sedimentation continued during Lebach time and a final upward movement increased the sedimentation, forming the upper conglomerate. The Zechstein Sea was never over this region and there is a gap in the sedimentary record in Ottweiler-Cuseler time.

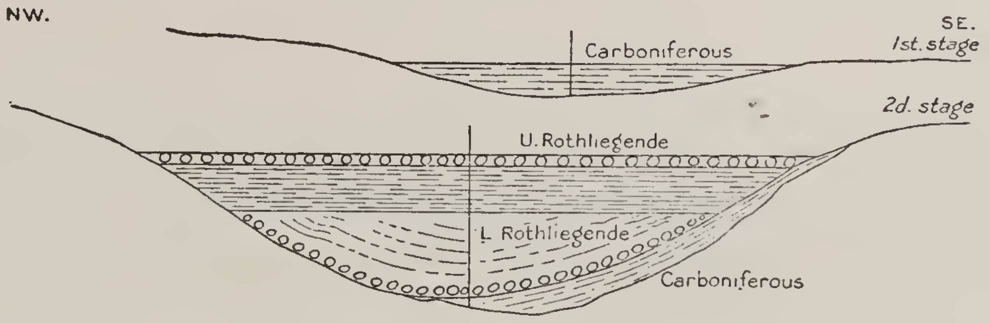

Fig. 5.—Section of Erzgebirge Basin between Zwickau and Chemnitz.

Brandes calls attention to the difference between the Erzgebirge Basin and the Döhlen Basin. In the former the Saarbruck-Ottweiler deposits are present and the Ottweiler-Cuseler absent, in the latter the conditions are reversed. He regards this as a local phenomenon due to different dates of faulting in the two regions, as the axes of the basin lie nearly at right angles to each other. He also suggests that the various small basins southeast of the main German depression, i. e., southeast of the line Königsee-Kostritz, which have their axes at right angles to the main trend of the Hercynian folds, are really deposits in tributary stream channels.

The flora of the Erzgebirge Basin is considered by Gothan as part of the flora characteristic of Saxony, but he notes the presence of the large number of silicified plant remains from the Zwickau-Altendorf region.

The fauna is very limited, perhaps because of unfavorable conditions for preservation, but as there are limestones and calcareous layers present in approximately the same position as in the Döhlen Basin it would seem that there was an actual absence of the fauna. *Phanerosaurus naumanni* H. v.M. from the north side of the basin, Oberlungwitz, is a Cotylosaur and is the only air-breathing vertebrate form known. The invertebrates are all more or less indefinite in position; such as are recorded belong to the Arachnida and the Myriopoda.

The Saal Basin lies north of the Döhlen and Erzgebirge Basins and includes the Harz region. In this area of sedimentation the Paleozoic deposits are largely covered by younger beds, mostly of the Tertiary and Quaternary. As shown in Born's map, figure 2, page 15, the Saal Basin was continuous, at intervals at least, with the Erzgebirge Basin. The following section of the region around Halle is from Beyschlag and K. v. Fritsch (1900).

Upper Rothliegende:
  Barren of fossils. Covering all irregularities of the older surface (5 to 10 meters).
  Great break and angular unconformity.
Lower Rothliegende:
  d. Very fossiliferous plastic clay (8 meters) of Sennewitz, and rotten porphyry tuff (71 to 78 meters).
  c. Petersberger porphyry (60 meters).
  b. Beds with *Walchia filiciformis* and *piniformis*; intercalated beds of porphyrite and perhaps quartz-porphyry (104 to 105 meters at Sennewitz).
  a. Great flow of Landsberger-Löbejüner porphyry, tuff, and arkose.
Ottweiler.

Wust (1907) has shown that the bottom layer of the Upper Rothliegende is a heavy conglomerate lying on a surface which had undergone long continued mechanical weathering (disintegration) but not chemical weathering (decomposition) and suggests that preceding its deposition there had been a long period of desert conditions.

The accompanying section, given by Walther (1923) for Halle, does not exactly correspond with that given by Beyschlag and Fritsch, but indicates the same general succession of events and shows the relation of the Rothliegende to these beds above and below.

At Zwickau the basal beds are conglomerates of mingled sedimentary and igneous material, with intercalated sandstones and gray shale which lie unconformably upon the Carboniferous. At Wettin and at Mansfeld the Lower Permian is conformable upon the Carboniferous but of less extent than at Zwickau. At both Wettin and Mansfeld the Permian opened with igneous activity and the basal beds are flows of porphyry with accumulations of argillite and tuff. At Mansfeld the period of igneous activity was followed by one of sedimentation with accumulation of conglomerate, sandstone and thin beds of coal; this was followed by the younger porphyry and then the conglomerate, sandstone and shale of the Upper Rothliegende.

Bunter sandstein.	Main Bunter sandstein.
Zechstein.	Obere Letten.
	Main anhydrite. Youngest salt.
	Unterer Letten.
	Edelsalz.
	Steinsalz. Old salt. Anhydrite.
	Oldest salt.
	Zechstein conglomerate.
Rothliegende.	Upper Rothliegende.
	Upper Rothliegende. Younger porphyry.
	Dividing beds. Sandstone, conglomerate, and thin coal.
	Older porphyry.
Carboniferous.	Steinkohle.

The sections given are fairly representative of the whole of the Mansfeld trough between Halle and the Harz. The presence of the coal seams and calcareous layers heightens the resemblance to the lower Rothliegende of other areas. The northern border of the Rothliegende lies near Magdeburg and Alvensleben, so that these deposits are perhaps in the nature of bordering deposits.

Ilfeld on the southwest of the Harz, and Oppenroda-Meisdorf on the northeast, were the sites of separate basins of sedimentation in the Lower and Middle Rothliegende; in the beginning of the Upper Rothliegende the latter basin was connected with the larger depression, but the former remained separate. (Born, 1923, page 523.)

The whole of the Saal region was connected with the North Suedetic Basin in Middle Rothliegende time by way of Laussitz, covering the granite now exposed, and it is not improbable that the whole of the Elbe Valley Basin was in connection with the depression at Weissig as the beds seem to have a common (Lebach) character. (Born, 1923, page 526.)

As a whole, the region of the Harz and the Saal was the site of pretty continuous igneous activity during all of Rothliegende time; the sedimentary beds were formed in short intervals of relative quiescense.

Born (1923, page 526) gives the following summary:

> In Lower and Middle Rothliegende time there was continued sedimentation with transgression of the borders of the sedimenting areas (1) into the North Saxon Basin and (2) into the Thuringian Basin, making apparent the existence of a continuous southwest-northeast depression corresponding to the Saar-Saal depression. During Lower Rothliegende time the greater part of the accumulation in the depression was of volcanic material with little sedimentation. There was an earth movement in Rothliegende time with some folding, but the exact time is uncertain; it was probably post-Lebach. The elevation and corresponding erosion was most prominent in the region southeast of the Harz and diminished in the same direction. The bulk of the material was transported toward the southwest where in the Thuringian Forest region there is the most complete representation of the Rothliegende and the greatest thickness of the beds.

Sedimentation on the south side of the Harz was more quiet and continuous than elsewhere in the Saal Basin. Geike, in his *Textbook of Geology*, gives the following general section:

- Upper Rothliegende:
  - Kreuznach beds. Red sandstone.
  - Monzig beds. Red shale.
  - Sotern beds. Melaphyr, tuff, and quartz-porphyry conglomerate.
- Lower Rothliegende:
  - (Lebach) Sandstone and conglomerate lying on black shale with poor coal.
  - (Cuseler) Sandstone and shale with some seams of coal resting on red and gray sandstone. Some bands of impure limestone.

This section indicates an approach to the sequence of deposition in the Thuringian Forest.

The flora of the Rothliegende from the Harz region, Saal Basin, as listed by Gothan, follows:

- Callipteridium gigas Gutb.
- Callipteris conferta Sternb.
  - flabellifera Weiss.
  - naumanni Gutb.
  - nicklesi Zeill.
- Caulipteris peltigera Brgn.
- Cyclopteris sp.
- Linopteris germari Gieb.
- Neuropteris gleichenoides Göpp.
  - planchardi Zeill.
- Odontopteris hercynica Romer
  - minor Brgn.
- Pecopteris arborescens Brgn.
  - bioti Brgn.
  - candolleana Brgn.
  - densifolia Göpp.
  - foeminaeformis Schlth.
  - oreopteridia Brgn.
  - pluckneti Schlth.
  - unita Brgn.
- Psaronius sp.
- Sphenopteris burgkensis Sterzel
  - landmanni Sterzel
- Taeniopteris plauensis Sterzel
- Calamites cruciatus Sternb. (Stachannularia tuberculata Schlth. and Annularia stellata Schlth.)
- Aphlebia germari Zeiller.
- Equisetites zeaformis Schlth.
- Sphenophyllum oblongifolium Germar.
- Sigillaria brardi Brgn. (various forms).
  - menardi Brgn.
- Cordaites principalis Germ.
- Walchia piniformis Schlth.
- Gomphostrobus bifidus H. B. Gein. (cone seeds of (?) Walchia).
- Cardiocarpus gutberi Gein. and other seeds.

The following is the faunal list of the Saal Basin:

PISCES:
- Acentrophorous glaphyrus Ag.
- Acrolepis exsculpta Kurtze.
  - sedgwicki Ag.
- Coelacanthus granulosus Ag.
- Dorypterus hoffmani Germar
- (Platysomus) althausi Munst.
- Hybodus macrothi Gein.
- Janassa bituminosa Schlth.
- Paleoniscus macropthalmus Ag.
  - magna Ag.

PISCES—*Cont.*
- Platysomus gibbosus Blv.
- Pygopterus humboldti Ag.
- ? Radamas macrocephalus Munst.

AMPHIBIA:
- Archegosaurus latifrons G. and D.
- Branchiosaurus (Protriton) tener Schnfld.
- Melanerpeton latirostris Cred.

REPTILIA:
- Parasaurus geinitzi H. v. M.
- Protorosaurus speneri H. v. M.

In the Thuringian Basin, according to Born, deposition was not strictly continuous in all parts and there are numerous minor variations in sections taken at different places. As combined from several sources the general section is as follows:

Upper Rothliegende:

5. Tambach beds. Conglomerate of igneous material, sandstone, and shale. *Walchia* and footprints. This series unconformable on the one below and recognizable at Tambach, Ilmenau, Elgersburg and Eisenach.

Middle Rothliegende = Tholier:

4. Oberhof beds. A period of eruptive activity; sheets of quartz-porphyry, with intercalated beds of shale, arkose (Steinach), and calcareous layers. (Kayser seems to indicate that the calcareous layers are tuffs). In these beds, at Oberhof, Leintal, and Friederichsroda, occur *Branchiosaurus*, *Gampsonyx*, and plants.
3. Goldlauter beds = Lebach. Coarse conglomerate and sandstone, with some clay shale. In the latter are occasional coal seams (Crock), with a considerable flora (*Walchia*, *Callipteris conferta*, *Annularia stellata*, *Calamites gigas*), kidney ore, and the fish fauna of Goldlauter, Friederichsroda, and Winterstein.

Lower Rothliegende:

2. Manebach beds = Cuseler.
   - Sandstone with six coal seams at Manebach, Gehlberg and Nordfleck. A flora containing *Walchia*, *Odontopteris obtusa*, *Pecopteris arborescense*, *P. abbreviata*, *Calamites gigas*, *C. suckowi*, *Sigillaria brardi*, etc.
   - Shale.
   - Conglomerate.
   - Conglomerate and sandstone with flora, *Odontopteris obtusa* and *Walchia piniformis*.
1. Gehren beds = Cuseler, lowest Rothliegende. Dominantly eruptive with lesser amounts of shale, arkose, sandstone, and breccia near the bottom. At Ruhla and Stockheim coal seams with *Walchia*, *Callipteris conferta*, *C. gigas*, *Pecopteris arborescens*, *Sigillaria orbiculoides* and *Cordaites*.

Walther (1923, page 81) gives the following tabular statement of the beds at Ilmenau:

Upper Rothliegende.	5. Tambach beds.	Upper conglomerate.	120 M.	
		Elgersburger sandstone.	50 M.	
		Lower conglomerate (100 M.) with tuff and sandstone.	300 M.	
	Unconformity.			
Middle Rothliegende.	4. Oberhof beds (Tholier).	Rumpelsberg porphyry (100 M.) with tuff and sandstone.	250 M.	
		Bundschildskopf porphyry.	50 M.	
	3. Goldlauter beds (Lebach).	Conglomerate clay shale and sandstone.	300 M.	*Acanthodes gracilis.*
Lower Rothliegende.	2. Manebach beds (Cuseler).	Conglomerate and black clay shale.		*Callipteris conferta.*
		8 beds with 3.5 M. of coal.	120 M.	*Calamites gigas.*
	1. Gehren beds (Cuseler, lowest Rothliegende).	Kickelhan porphyry and tuff.	170 M.	
		Hohlkopf melaphyr.	50 M.	*Walchia filiciformis.*
		Porphyrite with tuff.	430 M.	*Walchia piniformis.*
	Unconformity.			
	Lower beds.			

Potonié (1893) considers that numbers 3, 4 and 5 of the general section are transitional to the Zechstein. Sterzel considers the beds at Crock, in number 3, as equivalent to the Lebach beds. Number 4 is strikingly similar to the number 3 of the series in the Döhlen Basin, indicating a similar history of sedimentation in the two regions.

The small detached area in the northwestern portion of the Thuringian Basin has not the same section as the larger area in the southeast; the Middle Rothliegende is absent, suggesting a local uplift. The southeastern portion of the basin is extended southwest through Spessart and the Rhine region. The Rothliegende at Stockheim, Ebersdorf and Weiden was seemingly deposited in a distinct basin. According to Sterzel these beds are the equivalent of the Lower Rothliegende of the Döhlen Basin. From Ruhla-Brotterode to the Vosges only the Upper Rothliegende is present (Born, 1921).

Potonié (1896) says that the division of the beds in the Thuringian Basin into five divisions, by Beyschlag and others, on stratigraphic and petrographic grounds is not sustained by paleontological evidence; he suggests a tripartite division on the evidence of the fossils:

3. Tambach, Oberhof, and Goldlauter (partim) beds.
2. Goldlauter (partim), Manebach, and Gehren (exclusive of the Stockheim beds) beds.
1. Stockheim beds.

These carry according to his notation—

3. The IX flora.
2. The VIII flora.
1. The VII flora.

The Ottweiler flora (VI) is a transition flora between the IV and V, and the VIII, as is also to a degree the VII, but the VI shows closer relationship to the older floras IV and V, and the VII (by the appearance of such key fossils as *Callipteridium gigas*, *Callipteris conferta*, *C. naumanni*, *Walchia piniformis* and *W. filiciformis*) a closer relationship to the VIII. Potonié points out the difficulties in establishing the horizons and warns against the possibility of too definite statements on insufficient evidence. He also discusses the possibilities of an unequal rate of development in different areas, the possibility of the entrance of migrant faunas, and so forth.

The flora of the Rothliegende of the Thuringian region, as listed by Gothan, follows:

- Alethopteris grandini Brgn.
  - subelegans H. Pot.
- Aphlebia acanthoides Zeill.
  - erdmanni Germ.
  - flabellata Presl.
  - germari Zeill.
- Callipteris conferta Sternb.
  - juteri Zeill.
  - naumanni Gutb.
  - pellati Zeill.
- Callipteridium gigas Gutb.
- Cyclopteris scisa Gr. E.
- Linopteris germari Gieb.
- Neuropteris auriculata Brgn.
  - blissi Lesq.
  - cordata Brgn.
  - planchardi Zeill.
- Odontopteris minor Brgn.
  - osmundaeformis Schlth.
  - subcrenulata Rost.
- Pecopteris arborescense Schlth.
  - bredowi Germ.
  - candolleana Brgn.
  - densifolia Gopp.
  - foeminaeformis Schlth.
  - hemiteloides Brgn.
  - oreopteridia Brgn.
- (Crossotheca) pinnatifidia Gutb.
  - pluckneti Schlth.
  - polymorpha Brgn.
  - unita Brgn.
- Psaronius sp.
- Sphenophyllum sp.
  - oblongifolium Germ.
  - thoni Mahr.
- Sphenopteris cremeriana H. Pot.
  - decheni Weiss.
  - germanica Weiss.
  - ohmanniana H. Pot.
- Taeniopteris jejunata Gr. E.
  - multinervis Weiss.
- Annularia sphenophylloides Zenk.
  - spicata Gutb.
  - stellata Schlth (with Calamites cruciatus Sternb.)
- Calamites cruciatus Sternb.
  - gigas Brgn.
  - multiramis Weiss.
  - suckowi Brgn.
- Calamostachys thuringiaca Weiss.
  - tuberculata Sternb.
- Equisetities vaujolyi Zeill.
  - zeaformis Schlth.
- Sigillaria brardi Brgn.
- Baeria cf. digitata Brgn.
- Cordaites borassifolius Sternb.
  - palmaeformis Gopp.
  - principalis Germ.
- Dicranophyllum gallicum Gr. E.
- Lepidophyllum sp.
- Walchia filiciformis Schlth.
  - imbricata Schimp.
  - linearifolia Gopp.
  - piniformis Schlth.
- Zamites carbonarius Ren.
- Dadoxylon (silicified stems of Cordaites and Walchia), various seeds, and Pinnularai cappilacea L. o. H. (root of Calamites).

The faunal list of the Thuringian Basin follows:

Pisces:
- Acrolepis exsculpta Kurtze.
  - sedgwicki Ag.
- Amblypterus duvernoyi Ag.
- Globulodus macrurus Ag.
- Janassa bituminosa Schlth.
- Menaspis armatus Ewald.
- Paleoniscus arcuatus Edg.
  - frieslebeni Blv.
  - macropomus Ag.
- Platysomus gibbosus Blv.
- Pygopterus humboldti Ag.
- Wodnikia (Acrodus) althausi Munst.

Amphibia:
- Branchiosaurus amblystomus Cred. (Protriton petrolei Gaud.)
  - (Protriton) caduceus v. Amm.

Reptilia:
- Parasaurus geinitzi H. v. M.
- Protorosaurus speneri H. v. M.

Footprints:
- Aciabates sphaerodactylum (Pabst).
- Hardackichnium dolichodactylum (Hardaker).
- Eumeckichnium pachydactylum Nopsca.
  - gampsodactylum (Pabst).
  - v. minor (Pabst).
  - v. gracilis (Pabst).
  - v. minima (Pabst).
- Gampsodactylum friederichrodanum (Pabst).
- Herpetichnium hardakeri Nopsca.
  - acrodactylum (Pabst).
- Ichnium brachydactylum (Pabst).
  - rhopodactylum (Pabst).

Invertebrates:
- Gampsonyx.
- Estheria.

There is a series of small detached areas of Rothliegende extending from the Thuringian Forest to the Bohemian mass of gneiss and southward along its western border; these are known from Burggrub and Stockheim through Weidenberg, Erbendorf, Weiden and Amberg as far as Regensberg. The several small patches show over a thousand meters of Rothliegende, composed of the familiar succession of coal seams, eruptive layers, conglomerates, shales and so forth. So far as known no vertebrates have come from these beds. They perhaps indicate a transgression of the Upper Rothliegende to the south and southeast in the time of its greatest expansion.

The Mainz Basin is roughly outlined by the lines connecting Darmstadt, Frankfurt, Windecken, Budingen and Schollkrippen. It lies between the Taunus and the Odenwald and Spessart. Walther (1923) says that this area continued as a sinking region even in late Permian time and received an abundance of clastic material, sandstone and arkose, conglomerate and clay, with intercalated flows of melaphyr and porphyry. The section revealed at Altenstadt is reported by Meyer (1912, page 49) as follows:

Melaphyr.
Conglomerate.
Sotern (Calcareous oolite with small stegocephalians).
Tholier, transitional to the Sotern.
Lebach.
Cuseler with coal seams.

The exposures around Darmstadt are Middle Rothliegende according to Meyer; the beds at Heidelberg, commonly attributed to the Permian, he considers to have been deposited in a distinct basin separated from those of the Mainz Basin by the heights of the Odenwald.

Born (1921) believes that the Mainz Basin was connected with the Saar Basin through some channel entering its southwestern portion. The extension of the Mainz Basin to the southwest, or the development of some similar basin, made possible the accumulation of sediments which are probably those preserved on the borders of the Schwarzwald.

The Lower Rothliegende is lacking in the Schwarzwald and in the upper Rhenish provinces in general. It occurs in scattered localities, as at Nauenberg (Upper Lebach age) and in a drill hole at Offenbach at a depth of 200 meters (Lepsius, *Lehrbuch der Geologie*, Erster teil, page 404).

For the northern part of this area between Dieburg, Darmstadt, and Frankfurt, Lepsius gives the following section:

5. Loose clayey sandstone and clay shale with carnelian and dolomite nodules.
4. Upper conglomerate with porphyry and melaphyr pebbles and coarse kaolin sandstone.
3. Clay shale with sandstone and conglomerate.
2. Melaphyr flows.
1. Lower conglomerate and sandstone.

This section and the one following is, according to Credner, very similar to that found in the Vosges and in Alsace.

The following section is a composite, made up from sections given by Walther, Kayser, Lepsius, and others for closely adjacent localities in the Schwarzwald, as at Lahr, Baden-Baden, Oppenau, Offenburg, and Schöpfheim. It reflects the general sequence of events.

Upper Rothliegende:
    Arkose, lenses of dolomite, and layers of carnelian, red clays and speckled sandstone. A porphyry conglomerate at the base.
Middle Rothliegende (Lebach):
    Porphyry tuff and sheets of porphyry of equal age with the shales which contains *Gampsonyx*, *Estheria*, and *Walchia piniformis*.
Lower Rothliegende (Cuseler):
    Light gray arkosic sandstone, alternating with variegated clay shale and clay stone; some seams of coal.
    Conformable on the Carboniferous.

This region was not covered by the Zechstein Sea which, according to Walther (1923), did not extend farther south than the mouth of the Neckar. The Rothliegende extends as far south as Rheinfelden where 332 meters of red sandstone and marl were passed through in a drill hole.

Strigel (1922) gives a long and detailed account of the paleogeography of the Schwarzwald, tracing in particular the erosion plane produced in Upper Permian time. He sums up his conclusions as follows:

> 1. While in Upper Carboniferous and Permian irregular erosional land forms were developed (the Permo-carboniferous degradational surface) in Upper Permian there were developed degradational plains over wide areas that extended not only over the old crystallines but over the Permian sediments and eruptives (erosional plains). The plane surfaces of the crystalline rocks are probably not the relics of older high plains from earlier geological periods but rather, like the erosional surfaces of the Permian sediments, developed in Upper Permian time.

2. The planation did not result from the erosive action or the transgression of a Permian or early Triassic (Bunter) sea but by the action of terrestrial forces upon a dry land. The erosion and planation was accomplished by the forces at work in a periodically dry climate which prevailed from the Upper Rothliegende to the end of the Permian. The uneven degradational surfaces of the Carboniferous and the Permian were the result of the more humid climate of those periods.

3. The region of the Vosges and the Schwarzwald was land during the Zechstein time. In this period the planation was probably completed. The rock showed at the end of the Permian the final result of the (erosional) processes, a plain of erosion. The plateau of southwestern Germany was only a part of the great steppe-like plateau which bordered the Zechstein Sea. The upper Permian planation preceded a period of mountain making which began toward the end of the Upper Rothliegende and probably continued into the Zechstein.

4. The Permo-carboniferous deposits never covered the region of the Schwarzwald as a whole but were formed in separate channels and basins. Of special significance as collecting areas of debris were certain depressions of tectonic origin which had the general direction of the Variscan folds and were of the general type of terrestrial collecting areas. Into these same troughs flowed the lavas of the great eruptive outpourings. In the orogenic phases of the development some of the material collected in the troughs was raised and destroyed. The greater part of the degradation occurred in the pre-Triassic period of erosion.

5. The greater part of the dolomite accumulations in the Upper Rothliegende, especially the dolomite horizon near the upper limit, were deposited under the influence of the arid climate of the upper Permian in the form of superficial deposits like the incrustations or salt-pan deposits of recent half-deserts. The abundant silicification in the same horizon can be explained in the same way.

6. The general conformity of the Bunter deposits upon the Permian is due, in part, to a continuous deposition and, in part, to the development of a degradation plain above the Permian plain which was parallel to it. In the first case the upper beds of the Permian are the terrestrial equivalents of the deposits of the Zechstein Sea; in the second case this is not true.

7. The stage-by-stage transgression of the deposits of Bunter time over the pre-Triassic mountains of the Schwarzwald was not marine in character but terrestrial. This was accomplished by a widening and deepening of the basin in Bunter time which at the same time was kept filled by the accumulation of debris. Previous to the Permian the accumulation area was considerably larger, a geosyncline.

Hennig (1923) says that the Permian deposits of the Schwarzwald are not separable from the Carboniferous below or the Triassic above. The deposits were laid down with great irregularity in preformed depressions, and there is a continuous series of terrestrial deposits from the end of the Carboniferous into the Triassic. He regards the calcareous and dolomitic deposits, with nodules, occurring in the northern part of the region as perhaps evidence of a bordering transgression of the Zechstein Sea, but is careful to leave the question open. Hennig is insistent upon the irregular character of the deposits and the uncertainty in correlating the beds with known horizons in central Germany; he remarks that the folding at the end of Carboniferous time began earlier in the south than in the north and that the volcanic extrusions, porphyry and "grenz melaphyr" may have been formed in Lower Rothliegende in this region when it occurred only later to the north and east. The similarity of this progressive process to that of the Central Plateau of France is very striking. The whole sequence of the beds indicates an increase in aridity. Hennig cites the apparent decrease in the vegetal protecting covering of the eroding surfaces as well as the diminution in amount of fossils, the character of the sediments with torrential deposits and "dreikanter," and the increase in the proportion of red color as evidences of this process.

The following list of significant forms in the flora of the Schwarzwald Basin is given by Sterzel:

Callipteris conferta Sternb.
Odontopteris obtusa Weiss.
Pecopteris (Crossotheca) pinnatifidia Gutb.
Calamites cruciatus (infractus) Gutb.
Pterophyllum cotteanum Gutb.
    blechnoides Sandb.
Walchia piniformis Schlth.
Auricaryoxylon.
Cardiocarpus reniformis Gein.
Colpospermum sulcatum Presl.

The faunal list of the Schwarzchild shows that no vertebrates have been recovered from this region; the invertebrates are *Gampsonyx*, *Estheria*.

The Saar-Rhine Basin

Lepsius (*Lehrbuch der Geologie*, Erster Teil, page 145) says that this is one of the few regions in Germany where there is commonly no stratigraphic break from the Upper Carboniferous to the Triassic, except for the absence in some localities of the Zechstein. Because of the continuity of the beds the separation of the various stages can be determined only by paleontological evidence. This was attempted by Weiss (1869–1872) upon the basis of the contained fossil flora. The deposition in the region was accompanied, according to Lepsius, by continued upfolding of the underlying Devonian, producing saddles and depressions which in turn caused local differences in the generally continuous body of sediment. During Rothliegende time this movement culminated in the flows of porphyry and melaphyr, which not only contributed to the mass of clastic sediments but spread out as sheets, now intercalated with the sediments. The final movement was the depression of much of the area and the overflooding of the region by the waters of the Zechstein Sea.

The Permian deposits now appear between the old highlands, the Hunsruck, on the north and the younger Triassic of the Palatinate on the south. To the northeast they disappear beneath the younger beds of the Rhine Valley, approximately at a line drawn through Bingen, Kreuznach, and Kircheim-Bolander; to the southwest they disappear beneath the younger beds of the Rhine Valley a few miles east of the course of the Saar, between Saarbrücken and Merzig. A small detached area reveals the extension of the depression in the "Trier embayment" southeast of Wittlech on the south side of the valley of the Mosel.

This basin has been very thoroughly studied and detailed sections have been published for many localities. A generally accepted statement of the sequence of the beds is shown in the following composite section:

11. Upper Rothliegende (No fossils and no eruptives):
    7. Kreuznach beds. Red sandstone above and red ocherous shales (= Monzig beds of Gumbel).
    6. Wadern beds. Coarse melaphyr and porphyry conglomerate with brown-red sandstone.

1. Lower Rothliegende:
    5. Sotern beds. Porphyry breccia and conglomerate, claystone, and tuff; sandstone and shale with interbedded sheets of porphyry and melaphyr (Grenz melaphyr).
    4. Tholier beds. Feldspathic sandstone and conglomerate, arkose, and shale with intercalated sheets of melaphyr. (Horizons 4 and 5 are sometimes reckoned as Middle Rothliegende).
    3. Lebach beds. Gray arkosic conglomerate with sandstone, black shale, and thin limestones; at top a bed of clay-ironstone nodules containing fossils, intercalated beds of eruptives.
    2. Upper Cuseler. Arkose, sandstone, and shale. Some coal seams with plants.
    1. Lower Cuseler. Red and gray sandstone and variegated shale, with calcareous layers. Plants; first appearance of *Callipteris conferta* and *Calamites gigas*.

Haug considers that there was an important movement at the close of the Lower Rothliegende, i. e., between beds 5 and 6 of the section, but the German geologists regard it as of less importance. Haug regards the beds 1, 2, and 3 as equivalent to the Autunian of Central France. Grebe places the Sotern beds in the Upper Rothliegende.

Opposite page 350 in Frech's *Lethea Geognostica* is a table showing the equivalence of many local names, some now obsolete, which are still mentioned in the literature. It is reprinted here because reference to it will frequently help in avoiding confusion.

Bavarian Palatinate:	Saarbrücken:
Zechstein.	Bunter sandstein.
Upper Rothliegende or Donnersberg beds.	Kreuznach beds.
Red sandstone and clay, conglomerate below.	Monzig beds.
Unconformity.	Unconformity.
Grenz melaphyr.	Wadern beds (= Upper Sotern beds).
Lower Donnersberg.	Sotern (= Lower Sotern).
Middle Rothliegende.	Super-carboniferous, Permo-carboniferous.
Lebach beds.	Upper Lebach beds (Tholier).
	Lower Lebach beds (Lebach sandstone).
Main prophyry flow.	Yellow sandstone.
Lower Rothliegende.	
Upper Cuseler.	Upper Cuseler.
Upper Cuseler sandstone.	
Alsenz beds.	
Odenbach beds.	
Feist conglomerate.	
Lower Cuseler (Wolfstein or Königsberg beds).	Lower Cuseler,
Ottweiler,	

Born (1921, page 514) makes some comments, well worth considering. The sections in the different parts of the Saar Basin are very different, showing great irregularity in the rate and character of the sedimentation. The Lower Cuseler has its maximum at Glan and is reduced to 150 meters at Wendell. There is apparently a coastal phase at Lebach where the limestone is replaced by conglomerate; Devonian pebbles are found in the conglomerate at Lebach and at Cuseler, indicating an adjacent landmass, probably the Rhine mass.

There was also variation in the size of the areas of sedimentation, the Tholier is much limited, indicating possibly a deepening of the depression or a shrinkage of the waters and swamps.

The first of the eruptives appears in Sotern time; in Wadern time there was an expansion of the area of accumulation. Kayser notes that there is little or no volcanic material in the Cuseler beds but it becomes abundant above. In Sotern time a distinct basin is apparent at Trier, separated from the Saar Basin. Kreuznach time was again a period of great expansion of the accumulating area.

The Lower Cuseler has 12 to 14 species of plants in common with the Lower Rothliegende of the Plauenschengrund. Among others,

Odontopteris obtusa.	Calamites weissi (Cal. major).
Pecopteris hemiteloides.	Cyclocarpus cf. gibberosus.
Walchia piniformis.	Callipteris conferta (Call. prelongata).

Walther (1923) gives the following detailed section of the Rothliegende in the Palatinate.

			Meters	
Upper Rothliegende.		Standenbühler stage. Red clayshale and conglomerate. Winnweiler stage. Clayshale and melaphyr with basal conglomerate. Hochsteiner stage. Claystone and clayshale with Grenz melaphyr.	300–1,640	*Estheria.*
Lower Rothliegende.	Lebach beds, Middle Rothliegende.	Upper Lebach beds (100 meters). Red clayshale and conglomerate. Lower Lebach beds (300 meters). Gray sandstone and clayshale with melaphyr and porphyry.	400	*Callipteris conferta.*
	Upper Cuseler.	Hoofer beds. Red and gray clayshale and sandstone with "Kuseliten" Hoofer seam 12 cm.	300–400	*Estheria tenella,* *Anthracosia (Carbonicola) carbonaria,* *Paleanodon castor,* *Walchia filiciformis,* *Walchia piniformis,* *Callipteris conferta.* *Calamites gigas,* *Asterophyllites equisetiformis.*
		Alsenzer beds. Gray sandstone and clayshale with "Kuseliten and Tholiten."	450	
		Odenbach seam 20 cm. Odenbach beds. Gray clayshale and sandstone.	280	
	Lower Cuseler (Königsberg beds).	Wahnweg beds. Reddish sandstone and conglomerate.	300–400	
		Altenglan beds. Gray clayshale with calcareous beds.	50–200	
		Remigiusberg beds. Red sandstone and clayshale.	50–200	

Walther (1923) says of the Saar Basin that it was an area of depression in the Carboniferous and that filling continued throughout the Rothliegende but with a period of interruption marked by the unconformity at the top of the Ottweiler. The extent of the basin to the south is indicated by the occurrence of outcrops of Rothliegende on the edges of the Hardt Mountains (left side of the Rhine Valley) in several places where the streams have cut through the Bunter, as at Neustadt, east of Landau; 2 small areas just south of Landau, near Weissenberg; and just north of Bad Neuheim. (See Blatt 22, Strassburg, Lepsius, Geol. Kart. deutsch. Reichs.) Kayser (*Lehrbuch der Geologie*) says that the beds on the east and south sides of the Rhine Schiefergebirge, at Marburg, Frankenberg and Minden are special phases of the Zechstein, although they much resemble the Upper Rothliegende and are in part mapped as such (Blatt 18, Frankfort, Lepsius, Geol. Kart. deutsch. Reichs.).

Gothan lists the flora of the Rothliegende of the Saar region as follows:

- Callipteris conferta Sternb.
  - latifrons Weiss.
  - lyratifolia Göpp.
  - subauriculata Weiss.
- Odontopteris subcrenulata Rost.
- Pecopteris arborescens Brgn.
  - eucarpa Weiss.
  - oreopteridia Brgn.
  - (Crossotheca) pinnatifidia Gutb.
  - unita Brgn.
- Sphenopteris bockingiana Weiss.
  - decheni Weiss.
  - lebachensis Weiss.
  - triloba Weiss.
- Taeniopteris multinerva Weiss.
- Annularia spicata Gutb.
  - stellata Schlth.
- Asterophyllites longifolius Sternb.
  - equisetiformis Schlth.
- Calamites gigas Brgn.
  - suckowi Brgn.
- Cordaites sp.
- Lepidodendron posthumum Weiss.
- Sigillaria brardi Brgn.
- Walchia filiciformis Schlth.
  - flaccida Gopp.
  - linearifolia Gopp.
  - piniformis Schlth.
- Auricarioxylon and Dadoxylon (silicified stems of Cordaites and Walchia).
- Tylodendron speciosum Weiss (cavity filling of Walchia).
- Artesia (cavity filling of Cordaites).
- Various seeds.

The faunal list for the Saar region (Palatinate) is as follows:

PISCES:
- Acanthodes bronni Ag.
- Amblypterus duvernoyi Ag.
  - (Paleoniscus) gelberti Gldf.
    - latus Ag.
- Pleuracanthus sp.

AMPHIBIA:
- Small stegocephalia at Jakobsweiler and vicinity[1].
- Sclerocephalus sp.
- Branchiosaurus (Protriton) caduceus v. Amm.

INVERTEBRATES:
- Estheria.

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[1] Since this material was put into print an article by O. M. B. Bulman and W. F. Whitard, Proceedings of the Zoological Society of London, July 15, 1926, on Branchiosaurus and allied genera (Amphibia), describes new forms from Odernheim, *Leptorophus tener* (Schonfeld) and *Microlerpeton credneri* B. and W., and discusses the morphology of the primitive stegocephalians from various localities in Europe.

Distribution of the Tetrapod and Fish Faunas in the German Basins.

	Saar Basin.	Mainz Basin.	Saal Basin.	Thuringian Basin.	Harz Basin.	Erzgebirge Basin.	Döhlen Basin.	Middle Suedetic Basin.	North Suedetic Basin.
PISCES:									
Acanthodes bronni Ag	×							×	×
Acentrophorous glaphyrus Ag			×		×				
Acrolepis exsculpta Kurtze			×	×	×				
sedgwicki Ag			×	×	×				
Amblypterus decorus Edgr					×				
duvernoyi Ag	×	×		×				×	×
lateralis Ag	×								
latus Ag	×								
(Paleoniscus) obliquus Heckel		×							
reussi (Heckel)								×	
traquari S-W	×								
voltzi (Ag.)								×	
Coelacanthus granulosus Ag			×		×				
Conchopoma gadiforme Knerr	×								
Dorypterus hoffmani Germar		×	×		×				
(? Platysomus) althausi Munst		×	×						
Elonicthys macropterus Bronn	×								
Globulodus macrurus Ag				×		×			
Hybodus mackrothi Gein			×	×					
Janassa bituminosa Schlth		×	×	×		×			
Menaspis armatus Ewald				×	×				
Paleoniscus (Amblypterus) arcuatus Edgr				×					
decheni Goldf								×	
frieslebeni Blv		×	×	×		×			
(Amblypterus) gelberti Goldf		×							
kabalikae Gein								×	
luridus Heckel								×	
macropomus Ag				×					
macropthalmus Ag			×						
magnus Ag			×						
oelbergensis								×	
Platysomus gibbosus Blv			×	×	×				
Pleuracanthus carinatus Fr			×	×	×				
decheni Goldf	×	×						×	×
sessilis Jordan	×								
Pygopterus humboldti Ag			×	×	×	×			
Rhadamas macrocephalus Munst			×						
Sagenodus tardus Fr								×	
Wodnikia (Acrodus) althausi Munst				×		×			
AMPHIBIA:									
Acanthostoma vorax Crd							×		
Archegosaurus decheni Goldf	×						×		
latifrons G and D			×						
Branchiosaurus amblystomus (petrolei) Crd				×			×		
cauduceus v. Amm	×			×					
salamandroides Fr							×		
tener. Schon*			×						
Chelydosaurus vraini Fr								×	
Chelydcrpeton (Branchiosaurus) umbrosus Fr								×	
Discosaurus permianus Crd							×		
geinitzi Crd							×		
Melanerzeton fallax Fr								×	
latirostris Crd			×						
pulcherimum Fr							×	×	
pusillum Fr							×	×	
spiniceps Crd								×	
Paleosiren beinerti Gein								×	
Pelosaurus laticeps Crd							×		
Petrobates truncatus Crd							×		
Sclerocephalus bavaricus Branco	×								
crcdneri Fr								×	
haustri Goldf	×								
labyrinthicus Gein	×						×		
latirostris v. M	×							×	
(Osteophorus) roemeri v. M								×	
? Sparagmites arciger Crd							×		
Stegocephalia	×								
REPTILIA:									
? Datheosaurus macrurus Schrocder								×	
Edaphosaurus (Naosaurus) credneri Jaekel							×		
Kadaliosaurus priscus Crd							×		
Phanerosaurus naumanni v. M						×			
? Parasaurus				×					
Protorosaurus speneri v. M		×	×	×	×				
Paleohatcrria longicaudata Crd							×		
Stephanospondylus (Phanerosaurus) pugnax G. and D.							×		
Sphenosaurus sternbergeri Fitz			×						
Pantelosaurus saxonicus v. Huene							×		

*See note at foot of page 48.

From the material presented in the summary descriptions of the various German basins and from the accompanying faunal and floral lists, it is apparent that the region was one of isolated intermontane basins in the Variscan chain in Carboniferous time. During Rothliegende time the basins were gradually filled with debris at the expense of the intervening and surrounding highlands, until the sedimenting areas were connected by their expanding boundaries. The process of sedimentation was only interrupted by the short period of igneous activity between Middle and Upper Rothliegende time. Accompanying these physiographic changes was the continuous increase in aridity which culminated in the desert conditions of Upper Permian and Triassic time. Each basin had a history of its own but the differences were not sufficient to produce notably different faunas. The dominant progressive factors in the change of the environment were the steadily increasing aridity of the climate and the gradual but steady filling of the areas of sedimentation until the deposits overflowed their original boundaries, uniting the isolated basins and even covering the degraded highlands between.

That the original isolation of the basins is not reflected in a greater diversity of the fauna and flora is perhaps to be explained by the fact that each isolated basin, lake, or swamp held a relict group from the very widespread and homogeneous biota established in the coal swamps of the Carboniferous. This Carboniferous fauna and flora covered not only central and western Europe but extended to Great Britain and to North America (Watson, 1921).

With the inception of the Permian, or even before, in the Permocarboniferous, began the great series of changes which marked the oncoming of Mesozoic life and conditions—the beginning of the Red Beds (I. C. White), the appearance of *Schwagerina* (Beede), the appearance of *Callipteris* (Sterzel), the cessation of the first Hercynian movement in Europe (R. C. Chamberlin), the great depression and change in the insect life (Handlirsch), the culmination of the late Carboniferous and early Permian glaciation in the Southern Hemisphere (Rogers and others), the beginning dominance of the reptilian type of life (many authors), the alteration in the general dominant type of plants from Pteridophytes to Gymnosperms (Steenstrup, Clements, and others).

As in South Africa, North America, and France, the basins were the last holding grounds of the relict Carboniferous fauna and flora, and these were gradually invaded by the more advanced types from the surrounding highlands. Just as in North America, Permian conditions began in Germany in beds below the level where the usual formal line is drawn between the Permian and the Carboniferous. In France and Czechoslovakia, Permian conditions began well below this line and unquestioned Permian forms are found mingled with an abundant and typical Carboniferous life. It is the lack of recognition of this fact that has caused so much confusion in the

Distribution of the Tetrapod and Fish Faunas in the German Basins—Continued.

	Saar Basin	Mainz Basin.	Saal Basin.	Thurin-gian Basin.	Harz Basin	Erzge-birge Basin.	Döhlen Basin.	Middle Suedetic Basin	North Suedetic Basin.
Footprints—Amphibia:									
Aciabates sphaerodactylum (Pabst)				×				×	
Anthichnium anakolydactylum (Pabst)								×	
Hardachichnium dolichodactylum (Hardakker)				×					
Footprints—Reptilia:									
Eumechichnium pachydactylum Nopsca				×				×	×
gampsodactylum (Pabst)				×				×	×
v. minor (Pabst)				×				×	
v. gracilis (Pabst)				×				×	
v. minima (Pabst)				×				×	
Gampsodactylum albendorfensis (Pabst)								×	
friederichrodanum (Pabst)				×					
Herpetichnium acrodactylum (Pabst)				×					
ungulatum (Pabst)				×				×	
Ichnium brachydactylum Pabst				×					
rhopodactylum Pabst				×				×	
tetradactylum Pabst				×					
Saurichnites rittlerianus Hochst								×	
salamandroides Gein								×	
perlatus Fr								×	
Invertebrates:									
Gampsonyx	×	×		×					
Estheria	×	×		×					
Anthracosia goldfussana Gein		×				×			
(Cardinia) tellinaria Goldf						×			
stegocephalia Gein		×							

interpretation of the stratigraphy of the beds. In Germany, the wave of Permian conditions was somewhat later in making itself apparent; the conditions probably developed first upon the highlands, permitting the migrations of the higher types, and only later spread over the areas of the intermontane basins as these were filled and their level rose, at least relatively to the degrading highlands. The wave of changing conditions was as truly progressive in the region of the Variscan chain as it was in North America, but instead of advancing from east to west it descended from the highlands until it engulfed the aggrading basins below. The early appearance of the Pelycosaur, *Pantelosaurus*, in the lower beds of the Döhlen Basin is one of those happy occurrences where an accidental intrusion, either in life or as a transported cadaver, of the advanced upland fauna into the conservative environment of the basin permits a glimpse of what is ordinarily beyond the vision of the paleontologist.

The Permo-carboniferous deposits of central France lie in folds of Hercynian uplift but were close to the borders of the great central massif which was not affected by these folds. This relatively high land was under constant erosion during Stephanian time and apparently a favorable environment for the development of the more advanced types which easily found their way into the closely adjacent areas of deposition. This is apparent not only in the presence of "Permian" reptiles but of the distinctly Permian plant *Callipteris* mingled with the typically Carboniferous fauna and flora of the Autunian deposits.

Much the same thing may be said of the deposits of the Central Czechoslovakian basin. The advanced types of the more open land to the east (Purkenyě, 1902) and the Bohemian Massif to the west, developed under the favorable conditions of the advancing wave of change, easily invaded the pools and swamps before the relict Carboniferous fauna had waned or perished.

One is tempted to imagine the northern shores of the Mediterranean Tethys as something like the western shore of South America and to think that the more arid conditions crept slowly northward. The areas of Central France and the Bohemian Basin, more open to such effects, would have recorded them first.

The elevated ranges of the Hercynian chain determined the directions of migration and permitted wide dispersal in those directions. The Pelycosaurs and Cotylosaurs were able to follow the borders of the uplands at least, and the amphibians crept from pool to pool in the same directions. The Protorosauria apparently belonged in a different habitat and had a different geographical range; they never penetrated into the true intermontane basins and never crossed to the American continent. They were seemingly associated in some wise with the borders of the Zechstein Sea, perhaps littoral forms clinging to its shores.

Considering the proven presence of highly specialized forms of Pelycosaurs in Germany and Czechoslovakia and the certainty of the land connections between North America and Europe, we are surprised by the paucity of their remains. Because they apparently appeared earlier in North America and had their great expansion there we are tempted to consider that as the place of their origin, but a fortunate find of remains in Europe would entirely alter this opinion.

CHAPTER IV

SUMMARY DESCRIPTION OF THE PERMIAN DEPOSITS OF CZECHOSLOVAKIA

The Carboniferous and Permian deposits of Czechoslovakia are so closely associated and so difficult to distinguish, one from the other, that it will never, perhaps, be possible to draw a sharp stratigraphic line between the two, which will be equally acceptable to all workers. Here, as in so many regions, the formal division into successive layers with the appropriate fauna and flora assigned to each must give way to the recognition of a homogeneous set of life conditions appearing at different intervals of time and accompanied by the similar faunas and floras which only slowly show the changes due to the effect of evolution, emigration and immigration.

Katzer's clear exposition of the distribution of the Carboniferous and Permian beds gives the best idea of the general situation (Katzer, 1892). He says that in Czechoslovakia (Bohemia) four areas of Permian (or post-Carboniferous, as he calls it) can be distinguished.

1. The area west of the Moldau, including the typical localities of Kladno-Rakonitz, Pilsen and Manetin.
2. The area of the Erzgebirge, Brandau and Nikalsberg.
3. The area of southern and eastern Czechoslovakia, Budweiss, Bohm-Brod, Eisenberg and eastern Czechoslovakia.
4. The area along the foot of the Riesengebirge, roughly outlined by Rovinsko, Neu Paka, Nachod, Braunau, Tratenau and Hohenelbe, all of which are typical localities.

These areas present notable differences among themselves but retain a general similarity in the sequence of the deposits and the relation of the beds to the accompanying and preceding physiographic and diastrophic changes, that indicate their formation under the domination of uniform or uniformly changing conditions.

Katzer gives the following list as a schematic inclusive statement of the series of beds west of the Moldau. With the necessary omissions and modifications due to local conditions and increased knowledge it will serve as the key to the deposits in other areas.

Permian.
  Kuonova beds.
    Red sandstone and clay.
    Kaolin sandstone and conglomerate.
    Upper Coal.
    Layer of pyrite nodules.
  Nurschan beds.
    Sandstone and shale.
    Middle Coal.

Carboniferous.
  Radnitz beds.
    Sandstone and shale.
    Upper Lower Coal.
    Lower Lower Coal.
    Sandstone and conglomerate.

Out of all the confusion of various interpretations of the sections in different areas a general concensus among the Czechoslovakian geologists seems to accept the arrangement of Weithoffer (1902) as the most reasonable and accurate. This divides the Carboniferous and Permian beds of the various coal basins in four stages:

4. The Upper Red Beds, the Lihn, or Liehn, beds.
3. The Upper Gray Beds, the Schlan beds.
2. The Lower Red Beds, the Teinitz beds.
1. The Lower Gray Beds, the Kladno beds.

Of these, only the Upper Red Beds are definitely recognized by the Czechoslovakian geologists as of Permian age. The key of the whole complex appears to lie in the Kladno-Rakonitz Basin, to the northeast of Prague, and in the Pilsen Basin to the southeast. The following statement gives the various opinions of writers, so far as the author has been able to gather them, of the position of the beds in Czechoslovakia and their equivalence to beds in other parts of Europe.

Lihn beds = Braunau (Weithoffer), = Lower Rothliegende (Kayser, Broili) = Cuseler (Weithoffer, Broili), = Coblenzian (Broili) = Lebach (Frech in *Lethea Geognostica*), = Niederhässlich (Frech in *Lethea Geognostica*).

Schlan beds = Kuonova = Radnitz = Upper Ottweiler (Weithoffer, Broili), = Radowentz (Weithoffer), = Wettin (Weithoffer) = Rothliegende (Feistmantel (1883), Kayser), = Lower Lebach (Feistmantel (1883), Frech in *Lethea Geognostica*).

Teinitz beds = Nurschan = Saarbrucken (Purkenyě, Broili), = Upper Carboniferous (Thevinin), perhaps Permian (Thevinin), = Middle Ottweiler (Weithoffer), = Hexenstein (Weithoffer), = Mansfield (Weithoffer) = Rothliegende (Kayser), = Lower Cuseler (Feistmantel, Frech in *Lethea Geognostica*), = Lebach (Feistmantel), = No equivalent (Sterzel).

Kladno beds = Radnitz = Saarbrucken (Sterzel, Purkenyě), = Lower Ottweiler (Sterzel, Weithoffer), = Schadowitz (Weithoffer).

As is to be expected, the sections of the various basins do not agree in detail, the following composite sections taken from Fritsch (1883–5, vol. 1) will show the general arrangements of the beds and reflect the changes which occur in the region as a whole:

1. Composite section of the Rakonitz Basin.
    6. Limestone with scales of *Paleoniscus*.
    5 *Araucarites* sandstone.
    4. Black beds. The lower part with anthracite of Kuonova, etc.
    3. Sphaerosiderite concretions enclosing remains of animals near Hredel.

   2. A thick layer (not described by Fritsch but apparently composed of sandstone and clay) in which lies the coal of Nyran.
   1. Upper coal of Lubna, Moravia and so forth which is equivalent to the upper Radnitz beds.

   Unconformable on the Silurian.

2. Composite section of the Kladno-Schlan Basin.
   7. Rothliegende with concretions and layers of limestone and fish scales and *Anthracosia*. At Klobuck and Peruc.
   6. *Auracarites* sandstone.
   5. Beds with *Alethopteris serli*. Kivlic.
   4. Black beds and anthracite of Zabor.
   3. Zemech-Schlan horizon probably equivalent to the first coal of Nyran.
   2. Horizon in which the coal of Nyran is to be expected. Possibly the Rossitzer of Stur.
   1. Main coal of Kladno. Break. The beds unconformable on the Silurian.

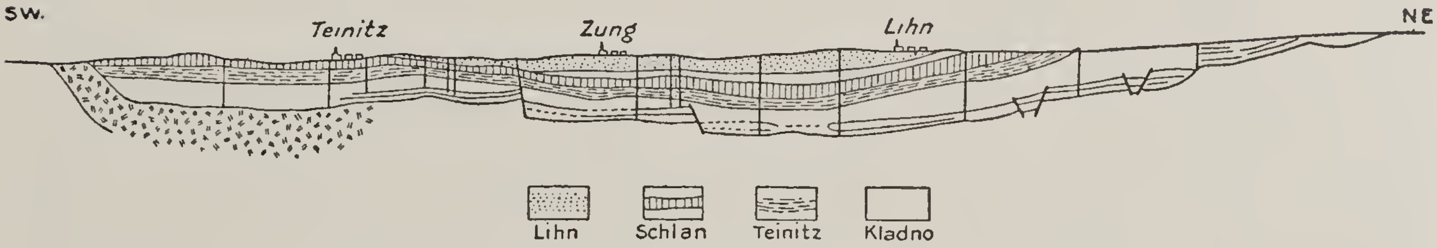

Fig. 6.—Sketch of Pilsen Basin. After Petraschek.

3. Composite section of the Pilsen Basin, made up from sections at four places, Tremosna, Nyran, Guscht, and Melsic-Holliken.
   20. Red clay (Kaolin).
   19. White clay.
   18. Sandy kaolin with inclined and horizontal layers of conglomerate.
   17. Arkose sandstone with kaolin-like cement and numerous yellow or red-brown stems of *Araucarites*.
   16. Yellow clay layers with fern impressions, red layers.
   15. Upper (Lihn) coal with layers of black *Araucarites*.
   14. Compact sandstone.
   13. Sandy clay alternating with compact sandstone; at bottom concretions with many plant impressions.
   12. Black clay shale; in upper part sphaerosiderite concretions with *Amblypterus*, below sphaerosiderite concretions with plants.
   11. Sandstone with pyrite concretions the size of a human head.
   10. Arkosic sandstone, alternating with clay shale, no *Araucarites*.
   9. Red clay shale.
   8. Green clay shale.
   7. Thin coal }
   6. Black shale } First coal of Nyran.
   5. Sandstone, clay shale, sandstone, clay shale.
   4. Cubical coal, separations of clay shale.
   3. Cannel coal, gas or platy coal with Amphibians.
   2. Sandstone and clay shale.
   1. Anthracite with separations of shale carrying Radonitz flora and *Bacilarites*. Upper layer is Bog-head.

Break. Unconformable on Silurian.

In these three sections it is possible to recognize pretty closely the four horizons of Weithoffer.

In section 1:
    Upper red = No. 6.
    Upper gray = Nos. 4–5.
    Lower red = No. 3.
    Lower gray = Nos. 1–2.
In section 2:
    Upper red = No. 7.
    Upper gray = Nos. 5–6.
    Lower red is represented by No. 4.
    Lower gray = Nos. 1–3.
In section 3:
    Upper red = Nos. 19–20.
    Upper gray = Nos. 10–18.
    Lower red = Nos. 8–9.
    Lower gray = Nos. 1–7.

Purkyně (1902[1], 1902[2], 1913) groups the upper beds as the Kuonova beds and the lower ones as the Nyran (Nurschan) or Nurschan-Radnitz beds, and this seems to be followed pretty generally by other writers. The opinion also seems to be rather general that it is only the Upper Red, Lihn, beds which are to be reckoned as Permian. Purkyně in his map (1909) and description of the Pilsen region (1913) gives the following summary statement of the upper beds.

General horizon.	Equivalent in lower Silesia.	Middle Bohemia.
Rothliegende.		Upper red clay shale = Lihn beds.
Upper Ottweiler.	Radonitz beds.	Dark gray clay shale in upper beds = Schlan = Kuonova beds.

His conclusions are drawn from a study of—

1. The Kladno, Schlan-Rakonitz Basin.
2. The Pilsen Basin.
3. The Morischau Basin east of Pilsen.
4. The Radnitz Basin lying between 1 and 2.
5. The Merklin Basin south of Pilsen.
6. The Manetin Basin north of Pilsen.

The two larger basins, 1 and 2, are very similar in the arrangement of the layers and he considers that they were very probably united at one time in a single large basin. The Kuonova beds of the Kladno-Schlan Basin carry a rich fauna of stegocephalia and although the flora has Permian elements it is, according to Suess (1905, page 162), thoroughly Carboniferous in character. The character of the fauna and flora indicates to Broili (1908) very definitely the Ottweiler age of the beds. On the other hand Kayser, in the third volume of his *Lehrbuch der Geologie*, seventh edition, very definitely states that the Permian carries coal beds and is separable with difficulty from the upper Carboniferous. He says that in general it is becoming recognized that the Steinkohl in Czechoslovakia and Moravia is rather Rothliegende than upper Carboniferous in age, and that this has long been recognized for western Czechoslovakia (including the Nurschan Gas or Platten Coal) and has recently been proven by Katzer (1892, page 1144) for the Rossitz Basin in Moravia. Haug (1907, page 796) regards the Gas Coal as equivalent to the Autunian.

Katzer (1892, page 1175) says of the Radnitz-Pilsen-Tremosna-Manetin area that it was originally a single collecting basin with a homogeneous development, and that the present isolation of the different occurrences and exposures is due to later erosion and "related effects" (post-Permian faulting). The coal deposits occur only near the borders of these basins, where the shallower water made possible the abundant growth of vegetation; they are absent in the central portion. The thickness of the beds varies in a manner impossible to predict ("unverkennbar"), probably due to the irregularities in the topography of the pre-Carboniferous surface. Katzer suggests that the irregularity in thickness may also be due in part to other causes, as meteorologic, especially active during Carboniferous time as opposed to the Permian (upper Carboniferous of later writers). In the latter time the deposits were formed under more uniform conditions as is shown by the greater uniformity of texture and thickness.

Area of the Erzgebirge

The small areas of Permian (?) near Brandau and Nikalsberg lie on the east slope of the Erzgebirge near the crest of the range. The Carboniferous series begins with a conglomerate of crystalline rocks lying directly upon the gneiss, this is followed by a sandstone rich in mica with layers of shale which gradually becomes the dominant feature toward the top and carries a layer of coal. The upper part, Permian of Katzer, is a layer of conglomerate, 60 meters thick, composed of quartz, porphyry, gneiss and fragments of shale in a red clayey, sometimes sandy, matrix; there is also an unworkable layer of anthracite. The small patch just north of Nikalsberg is an isolated layer of anthracite enclosed between porphyry and gneiss; it is apparently Carboniferous in age. The Brandau occurrence seems to be more in the nature of a true filling of a natural depression. If these isolated occurrences are part of the deposits on either side of the crest, the Chemnitz-Zwickau on the west and the Kladno-Rakonitz on the east, they are of importance in indicating the former extent of the Carboniferous area of sedimentation. Katzer suggests that they may be outlying parts of either. The evidence is too slight to be determinative; all that can be said is that conditions existed in the region, now the elevated portion of the Erzgebirge, similar to those on both the east and west sides of the area. Neither of these areas is shown on the Lepsius map of Germany or the latest geological map of Czechoslovakia as either Carboniferous or Permian. According to Gothan, in manuscript, the flora from Brandau is Carboniferous in age.

The Permian deposits of eastern and southern Czechoslovakia include the several occurrences east of the Moldau and south of the Elbe and Adler Rivers. Katzer includes in this division the exposures at Landskron and Giersberg, but in this review they will be included in the discussion of the Moravian region.

All of the deposits occur in small, isolated basins extending from Bohm-Brod, east of Prague, to a little north of Budweiss. Suess states that they are remnants of a continuous deposit preserved by down-faulting. The most southern of the basins, northeast of Budweiss, is a small accumulation in a depression in the gneiss; its greatest axis runs northeast–southwest for about 7.5 km. and the least axis is not greater than 2.5 km. According to Strasky (1856) the succession of beds is as follows:

	Meters
3. Red, brown and gray-green, sometimes micaceous sandstone; sometimes shaly from the excess of mica and mostly very fine grained. At the locality west of Libnitsch there are limestone lenses with fish scales	200
2. Fine-grained sandstone and clay shale with plants and a seam of anthracite.	
1. Conglomerate or sandy arkose	120

Strigel (1914) suggests that the steep inclination of the beds, both at Budweiss and at Schwartz-Kostelet and Bohm-Brod, indicates folding and accentuation of the basin character of the areas subsequent to the time of deposition.

Between the areas near Budweiss and Bohm-Brod there are several of very limited extent. Near Tabor there is a small area of red and gray sandstone, in which occur many silicified stems of *Psaronius radiatus* Sternb., *P. zeidleri* Corda, *P. asterolithus* Cotta, and *Myelopelys medullosa* Cotta. North of Tabor, near Wlaschin, the section revealed in mines is—

3. Gray, heavy-bedded clay shale becoming sandy and red toward the top.
2. Thin seams of glistening dark-brown coal, which breaks in prisms.
1. Gray, muscovite-bearing sandstone, imperfectly bedded.

In these beds occur *Spongilopsis dyadica* Gein., *Sphenopteris naumanni* Gutb., *Pecopteris arborescens* Schloth., *Cordaites* sp., *Cardiocarpon orbiculare* Ett., fish scales and coprolites. North of Wlaschin, at Diwischav, the section is—

2. Red micaceous sandstone.
1. Conglomerate.

At Schwartz-Kostelet and Bohm-Brod the Permian lies directly upon the granite and gneiss; it is covered to the north and east by younger beds. The section in general is—

2. Loose sandstone with red, brown, reddish-yellow and gray bands, locally alternating with conglomerate, and including layers of gray clay shale.
1. Conglomerate with blocks of crystalline rocks up to the size of a human head, with a red micaceous clay matrix.

The small patches of Permian lying on the crystalline rocks of the Eisenberg near Sec are made up of fairly hard red-brown sandstone, arkose and conglomerate. Locally, somewhat west of Sec, there is crumbly quartz sandstone with a red, micaceous, clayey matrix; in rare patches there is a firmer conglomerate with a clay shale. At the foot of the Kankova Mountains there are blocks of reddish chert and jasper which are perhaps the remnants of a Permian layer removed by erosion (Katzer, 1892, page 1186).

The Permian deposits of Czechoslovakia lying along the southern face of the Riesengebirge have been described in connection with those of the Middle Suedetic Basin (pages 23 to 26).

Between Nachod and Reichenau there are a few disconnected occurrences which link the deposits on the slope of the Riesengebirge with those of Moravia, the Rossitz beds. These, the Rossitz beds, begin a little east of Giersberg and pass near Landskron, Boscowitz, a little east of Brunn, Kromau, near Znaum, and so toward Krems on the Danube, in lower Austria; a great curve, convex to the east, following the outline of the Moravian Highlands. All the deposits lie unconformably upon the Carboniferous and older beds in a pre-Permian depression which according to Strigel (1914) is a tectonic depression continuing the course of the Adlersberg. At Rossitz, east of Brunn, the beds lie directly upon the crystallines, showing a transgressive overlap on the lower Carboniferous beds. There are three beds of workable coal at Rossitz, which are lacking both north and south of that place. Katzer (1892) considers these beds, from floral evidence, as equivalent to Upper and Lower Rothliegende, the Middle Rothliegende being lacking. The flora of the three beds is reported as—

Upper bed.	Middle bed.	Lower bed.
Calamites gigas	Sphenopteris oblongifolium	Idem.
Odontopteris subcrenulata	Idem.	
Callipteris conferta = prelongata.		
Alethopteris grandis.		
Pecopteris arborescens	Idem	Idem.
Lepidodendron sternbergi	Pecopteris oreopteridia.	
	hemiteloides	Idem.
	densifolia	Pecopteris pluncknetti.
	unita	Idem.
	Neuropteris cordata.	
	Walchia piniformis	Cordaites principalis.

Branchiosaurus (*Chelyderpeton*) *moravicus* Fr. and *Melanerpeton falax* Fr. have been found in a black shale at Lotka, which suggest the horizon of the Braunau beds.

The difficulty in separating the Permian from the Carboniferous in Czechoslovakia is increased by the fact that the series of deposits are undisturbed and there are no eruptives present. In the great majority of cases the Permian, when present, lies conformably upon the Carboniferous and can not be higher than the Cuseler. Much that has been reckoned as Permian must now be placed in the upper Carboniferous.

The relation of the deposits of the central basins of Czechoslovakia to the eastern deposits and to those in Moravia is indicated by the presence of the sedimentary beds at Schwartz-Kostelet and Bohm-Brod which are exposed between the granites of the central massive and the gneiss of the Moravian Highlands. The lower beds are conglomerates, overlaid by red sandstones and clays. Some of the German geologists are inclined to regard these beds as of Lower and Middle Rothliegende age because of the similarity of succession with that of Germany—"Brandschiefer" at the bottom, followed by coal seams and a considerable amount of calcareous material toward the top.

Weithoffer (1902) in summing up his discussion of the beds makes the following remarks, freely translated:

> "If it is admitted that the correlation suggested (upper and lower red and gray beds) is possible, then the Permian and Upper Carboniferous had a surprisingly large distribution over Czechoslovakia, Moravia, lower Silesia, and Germany, with a remarkable similarity of facies.
>
> "The feldspathic and Araucarite-bearing arkoses are in nearly all localities (doubtful in a few) equal to the middle Ottweiler. The material was derived from the granite and gneiss of adjacent highlands; the abundant kaolin of certain beds and localities is due to the secondary decomposition of the feldspars for they were originally deposited in the undecomposed condition, though no granite or gneiss pebbles have been found with them. Some of the clays are always unfossiliferous whether they be white, red or gray. The Carboniferous flora is distinctly regressive through the series and there is a gradual appearance of conifers, which is taken to indicate a progressive change in the climate. It is usually assumed that the lower, Carboniferous, sandstones and arkoses were deposited in great lake basins or inland seas, but an analysis of the material and deposition of the material presents many puzzles upon this hypothesis.
>
> "The small size of the elements, the widespread distribution of the arkose, and the fact that the conglomerate is confined to the center of the basins and unmixed with other material are among the most striking of the puzzling conditions. The sudden appearance of the Araucarites and the equally sudden disappearance of the Carboniferous flora are equally puzzling."

In answering these problems Weithoffer suggests a desert condition of sedimentation rather than in a lake or inland sea. He cites many analogous conditions from Walther's description of the desert. He assumes that the quartz and feldspar, which are of nearly equal specific gravity have been swept by the wind into great accumulating basins. The conglomerates, which are of phyllitic material rather than granite or gneiss, were swept in by streams rising from occasional torrential rains such as are characteristic of arid regions. The absence of mica in the sandstone and conglomerate matrices he attributes to the easier transportation of the mica flakes by the wind and to their easier decomposition; perhaps the mica was carried to locally damper spots and accumulated there to form the clays which are not uncommonly micaceous. The disappearance of the Carboniferous flora and the appearance of the Conifers is also an indication of arid condition. The silicification of the stems of the Conifers is common in the deposits of desert lands (such an occurrence is strikingly present in the Mokattam); forests are often buried in dune sand as in inner Asia, Arabia and Turkestan and it is exactly under these (desert) conditions that we find "the uniform distribution of a single horizon of wide extent and the similarity of the components" (Fraas). To this evidence he adds that of the absence of the remains of aquatic animals.

He concludes that the presence of the very fine-grained, uniform, red and gray, unfossiliferous clays show that they were accumulated by wind action in a desert or upon a steppe. Steppes are commonly surrounded by dunes and the remains of plants may be swept on to the surface of the steppe, or, in times of greater humidity, might even advance out upon the steppe; such periods of greater humidity might cause the development of swamps into local bodies of water which would support for a time a luxuriant vegetation. The lack of ripple marks and the red color of the beds are also cited as evidence of desert conditions (but these may be regarded as of little value as it has been repeatedly shown that they are not necessarily indicative of the conditions assumed by Weithoffer—The author).

The alternation of the fine clays with the arkoses and feldspathic sandstones is also explained by the action of the wind which in one instance might act as a very efficient sorting agent and at another sweep all the material together in a heterogeneous mass. The absence of granite and gneissic pebbles in the conglomerates is explainable by the assumption that these materials lay long exposed to the decomposing agents and were not sufficiently coherent to bear transportation to the final resting places.

Broili (1908) has given a very careful analysis of the fauna and flora of the Kuonova and Nurschan beds and concludes that they are definitely upper Carboniferous. His conclusions are as follows:

1. The following purely Carboniferous forms are peculiar to the Nurschan and Kuonova horizons:
   Dolichosoma, Ophiderpeton, Urocordylus, Dendrerpeton, ?Loxoma, Ptyonius.
2. Two genera in the Nurschan and Kuonova horizons are both Permian and Carboniferous, *Branchiosaurus* and *Hylonomous.*
3. *Naosaurus*, *?Macromerion* and *Sclerocephalus* are now known only from the Nurschan horizon and from Permian beds of other places.
4. Certain forms show great similarity to, and relationship with, forms that are known from the Carboniferous beds elsewhere as—

   Sparodus with *Batrachiderpeton* and *Hylerpeton.*
   Scincosaurus with *Keraterpeton.*
   Microbrachis with *Tuditanus* and *Cocytinus.*

> 5. The remainder of the fauna is unique for Nurschan and Kuonova—
>
> *Dawsonia.*
> *Adenoderma.*
> *Limnerpeton.*
> *Seeleya.*
> *Ricnodon.*
> *Orthocosta.*
> *Hylerpeton (? = Hylonomus).*
> *Diplovertebron.*
> *Cochleosaurus.*
> *Nyrania.*
> *Gaudrya.*
> *Proprierpeton.*
> *Nummulosaurus.*
> *Gephyrostegus.*
>
> "Two-thirds of the fauna is comparable with forms from other localities which are completely Carboniferous, only one-third is comparable to Permian forms. It is surprising that only one reptile is known, *Naosaurus*; this also speaks for the Carboniferous age.
>
> "Of the fish, 27 species are described. Two are known elsewhere; one of these is doubtfully identified as *Acanthodes bronni* which occurs at Lebach. The other, *Ctenodus obliquus* H & A, is known in considerable abundance from the Carboniferous of England.
>
> "The flora from the gas shales of Nurschan has, according to Feistmantel, 55 species, 7 of these are Permian. Later Feistmantel extended his list and corrected it, recognizing that almost all of the species occur in the productive Steinkohl.
>
> "It therefore remains incomprehensible why the bed at Nurschan, especially, although the flora was determined by Feistmantel as Carboniferous, is placed in the Permian on the evidence of the Stegocephalia, when in the whole fauna only a single form occurs which is known from the Permian, *Branchiosaurus*, in the light of the fundamental law that a fauna belongs in the geological period with which the majority of its elements is common."

Ryba (1903), later than Feistmantel, records 72 species of plants out of which only two, *Schutzia anomola* Gein. and a poorly preserved frond of a fern, *Pecopteris pinnatifidia* Schutz., are Permian. Ryba regards the flora as belonging in the Ottweiler.

In a second paper on the Kuonova horizon in the Pilsen Basin Ryba (1906) records 50 species from which he concludes that the horizon is equivalent to certain horizons in the Plauenschengrund and in the Saar-Rhine region, *i. e.*, Cuseler. Broili notes that of the 50 species 8 are true Permian, but that only 3 of these are confined to the Permian, *Callipteridium crassinervum*, *C. subelegans* and *Annularia spicata*, and that these species are very rare in the Kuonova horizon. His conclusion is that the Kuonova beds carry a transition flora and are somewhat younger than the beds of Commentry in France and so referable to either the Permian or the Carboniferous. The fauna of the Kuonova beds is older than that of the Plauenschengrund which is Cuseler, and is upper Carboniferous. Broili concludes:

> "A comparison of the Czechoslovakian beds with those of other regions show:
>
> 1. The beds of Kuonova are to be correlated with the Ottweiler.
> 2. The older beds of Nurschan are to be correlated with the Saarbrucken beds.
> 3. The geological relations indicate that the beds of Nurschan and Kuonova = Ottweiler and Saarbrucken beds.
> 4. The flora of the Nurschan beds is, according to the evidence of O. Feistmantel and Ryba, Carboniferous and indicates a transition horizon that is rather upper Carboniferous than lower Permian. The fauna is, on the basis of the dominant Carboniferous forms, upper Carboniferous.

5. The presence of the snake-like forms or long-tailed forms, such as *Urocordylus*, *Dolichosoma*, *Ptyonius*, *Scincosaurus* (near *Ceraterpeton*), are all typical Carboniferous; only rare forms as *Hylonomous* occur in the Permian.
6. Certain forms as *Cochleosaurus*, *Nyrania*, *Sclerocephalus* are new and are forerunners of the rhachitomus Stegocephalia which have their greatest development in the Permian.
7. The transition to the Permian is shown in Czechoslovakia in the Braunau beds which have a true Permian (Cuseler) age and where further Permian elements appear in the genus *Melanerpeton*, *Sclerocephalus*, and the Archegosaurus-like *Chelydosaurus* (*Chelyderpeton*)."

The following floral lists of the central basin of Czechoslovakia have been revised from Purkyně by Gothan. Evident slips have been eliminated by Doctor Gothan but the determination of the specimens is not by him. According to Doctor Gothan these beds are equivalent to the beds of Zwickau and Saarbrucken. Species marked "K" occur also in the apparently Permian beds of Kuonova. Those marked with an + are characteristic of the basin.

- Alethopteris bohemica Franke.
  - grandini Brgn.
  - lonchitica Schlth.
  - serli Brgn.
- Alloiopteris coralloides Gutb.
  - sternbergi Ettgsh.
- Aphlebia crispa Gutb.
- Cyclopteris orbicularis Brgn.
- Desmopteris elongata Presl.
- Linopteris neuropteroides Gutb.
- Mariopteris ? latifolia Brgn.
  - muricata Schlth.
- Neuropteris gigantea Sternb.
  - heterophylla Brgn.
  - obliqua Brgn.
  - rarinervis Bunb.
  - scheuchzeri Hoff.
  - tenuifolia Schlth.
- +Noeggerathia foliosa Sternb.
  - intermedia Feistm.
- Odontopteris reichinana Gutb. (Apparent confusion with Neuropteris subcrenullata (Rost) Zeiller K. stradonitzensis?.)
- Palmatopteris furcata Brgn.
- Pecopteris arborescens Brgn. K.
  - foeminaeformis Schlth. K.
  - miltoni Artis.
  - oreopteridia Brgn. K.
  - pennaeformis Brgn.
  - pluckneti Schlth. K.
  - plumosa Art.
  - unita Brgn. K.
- +Rhacopteris asplenites Gutb.
- Sphenopteris (Oligocarpia) brogniarti Stur.
- Sphenopteris macilenta L. and H.
  - obtusiloba Brgn.
  - rutaefolia Gutb.
- Caulopteris phillipsi L. and H. (Stem of fern).
- Megaphyton giganteum Goldenb.

- Psaronius sp. (Stem of fern showing structure.)
- Annularia stellata Schlth. (Florescence: Stachannularia tuberculata Sternb.) K.
- Annularia sphenophylloides Zenker K.
  - radiata Brgn. ? (Florescence: Calamostachys ramosa Weiss.)
- Asterophyllites equisetiformis Sternb.
  - grandis Sternb.
  - longifolius Sternb. (Florescence: Calamostachys ludwigi Carr.)
- Calamites carinatus Strnb. (Leaves: Annularia radiata Brgn.)
  - cisti Brgn.
  - cruciatus Sternb. K.
- Calamites paleaceus Stur.
  - schutzei Stur.
  - semicircularis K.
  - suckowi Brgn. K.
  - undulatus Sternb. K.
- Huttonia spicata Sternb.
- Macrostachya infundibuliformis Brgn.
- Myriophyllites gracilis Artis. (Root of Calamites)
- Palaeostachya elongata Presl.
  - ettinghauseni Kidst.
- Pinnularia capillacea L. and H. (Root of Calamites.)
- Sphenophyllum cuneifolium Strnb.
  - emarginatum Brgn. K.
  - majus Bronn.
  - myriophyllum Crep.

- Asolanus camptotaenia Wood. K.
- Bothrodendron minutifolium Boul.
- Lepidodendron aculeatum Strnb.
  - dichotomum Strnb.
  - haidingeri Ettgsh.
  - lycopodioides Strnb.
  - obovatum Strnb.
  - rimosum Strnb.
- Lepidophloios larcinus Strnb. (with Halonia).
- Lepidophyllum maius Brgn.
- Lepidostrobus goldenbergi Schimper.
  - variabilis Gein.
- Lepidophyllum triangulare Zeil.
- Sigillaria alveolaris Brgn.
  - elongata Brgn.
  - scutellata Brgn.

Sigillaria tessellata Brgn.
trigonia Strnb.
Sigillariostrobus feistmanteli O. Feist.
Stigmaria ficoides Brgn. K.
Artesia transversa Strnb. (Filling of pith cavity of Cordaites.)
Cordaites principalis Germar. K.
Cordaianthus pitcairniae L. and H.
Cardiocarpus gutbieri Gein.
Rhabdocarpus amygdalaeformis Gopp. and Berg.
Samaropsis type orbicularis Ettsgh.
Trigonocarpus noeggerathi Sternb.

To this list would be added by Ettinghausen:

Calamites goepperti Ettgsh.
Cyclopteris haidingeri Ettgsh.
Diplotmena gilkineti Stur.
Diplotegium browianum Corda.
Rhodea *cf.* subpetiolata H. Pot.
Sphenopteris spinosa Göpp.

The flora of Stradonitz is approximately the same age as that of the Pilsen Basin. The forms marked with an (+) are unique in the Stradonitz area:

Aphlebia sp. ("caryotoides" Sternb.)
Linopteris neuropteroides Gutb.
+Neuropteris stradonitzensis Andr.
Paleopteridium reussi Ettgsh.
Rhacopteris asplenites Ettgsh.
+Sphenopteris haidingeri Ettgsh.
+Triphyllopteris rhomboidea Ettgsh.
Annularia stellata Schlth.
Sphenophyllum cuneifolium Strnb.
Cordaites ? borassifolius Strnb.
Cordaianthus sp.
Samaropsis *cf.* fluitans Dawson.

The flora of the Kuonova (Permian) beds of the Pilsen Basin is given below. These beds contain also Stephanian elements.

Alethopteris bohemica Franke.
Aphlebia erdmanni Germar.
germari Zeill.
Callipteridium gigas Gutb.
pteridium Schlth.
triangulare Franke.
Callipteris, apparently absent.
Linopteris germari Giebel.
Pecopteris bredowi Germ.
hemiteloides Brgn.
Calamites gigas Brgn.
Sphenophyllum oblongifolium Germ.
Sigillaria brardi Brgn.
Poacordaites linearis Gr. E.
Rhabdocarpus disciformis Strnb.
Samaropsis crampi H. Pot.
Walchia piniformis Schlth.
filiciformis Schlth.

The following is a list of the Rothliegende flora of Rossitz in Moravia. Original by Stur and Katzer, critically revised by Gothan:

Alethopteris longifolia Presl (possibly Desmopteris longifolia; it appears to me scarcely possible, perhaps, Pecopteris unita? Gothan).
Alethopteris serli Brgn. (evidently wrongly determined. Gothan).
Callipteris conferta Strnb.
Dictyopteris neuropteroides Gutb. (may be Linopteris germari Giebel).
Mariopteris muricata. (certainly a wrong determination, probably Callipteris conferta. Gothan).
Neuropteris auriculata Brgn.
Odontopteris alpina Presl.
brardi Brgn.
"crenulata" Brgn. (unknown species. Gothan).
minor Brgn.
obtusa Brgn. (probably subcrenulata Rost. Gothan).
Pecopteris arborescens Brgn.
candolleana Brgn.
Pecopteris dentata Brgn. (= P. plumosa Artis, occurrence improbable. Gothan).
oreopteridia Brgn.
Sphenopteris rossitzensis Stur (? Callipteris Gothan).
Annularia stellata Schlth.
sphenophylloides Zenker.
Asterophyllites equisetiformis Strnb.
Calamites approximatus Brgn.
multiramis Weiss.
"varians" (not a true species, cast of pith cavity. Gothan).
Sphenophyllum oblongifolium Germ.
Lepidodendron rimosum Strnb. (occurrence scarcely to be assumed. Gothan).
Sigillaria lepidendrifolia Brgn. (indeterminate specimen).
Walchia piniformis Strnb.

The following faunal list includes the known forms from Czechoslovakia (Bohemia and Moravia):

Fauna of the Czechoslovakian Basins.

	West of the Moldau.	Middle Suedetic Basin.	Eastern Czecho-slovakia-Moravia.
PISCES:			
Acanthodes bronni Ag	K	×	
Amblypterus duvernovi Ag		×	
reussi (Heckel)		×	
voltzi (Ag.)		×	
Anaglyphus insignis Rzehak			×
Diplodus bohemicus Qnstd	N K		
Elonicthys? gigas Fr	K		
Gyrolepis speciosus Fr	K		
Hybodus sp	K		
Megalicthys nitens Fr	K		
Orthocanthus bohemicus Fr	N K		
? gibbosus Fr	N K		
Paleoniscus dechenni Goldf		×	
kabalikae Gein		×	×
katholitzkianus Rzehak			×
moravicus Rzehak			×
oelbergensis		×	
promptus Rzehak			×
Phyllolepis concentrica Ag	N K		
Petalodus ?	K		
Pleuracanthus carinatus Fr		×	
Pleuracanthus (Xenacanthus) decheni Goldf	N K	×	
Sagenodus aplanatus Fr	K		
inaequalis Ow	K		
tardus Fr		×	
Sphaerolepis kuonovensis Fr	K		
AMPHIBIA:			
? Adenoderma gracilis Fr	N		
Branchiosaurus (Chelydosaurus) austraicus Fr. (= moravicus Mak.)		×	×
robustus Fr	K		
salamandroides Fr	N	×	
(Chelyderpeton) umbrosus Fr		×	
? venosus Fr	K		
Chelydosaurus (Gaudrya) latistoma Fr	N		
vraini Fr	N		
Cheyderpeton (Branchiosaurus) umbrosus Fr		×	
Cochleosaurus bohemicus Fr	N		
Dawsonia polydens Fr	K		
Dendrerpeton deprivatum Fr	N		
? foveolatum Fr	K		
pyriticum Fr	N		
Diplovertebron punctatum Fr	N		
Dolichosoma angustatum Fr	N		
crenatum Fr	N		
longissimum Fr	N		
scutiferum Fr	N		
Gephyrostegus bohemicus Jaekel	N		
Hylonomus acuminatus Fr	K		
longicostatus (Fr.)	N		
? pictus Fr	K		
Lepterpeton sp. Fr	N		
Limnerpeton caduceum Fr	N		
elegans Fr	N		
difficile Fr	N		
dubium Fr	K		
laticeps Fr	N		
macrolepis Fr	N		

Fauna of the Czechoslovakian Basins—Continued.

	West of the Moldau.	Middle Suedetic Basin.	Eastern Czecho-slovakia-Moravia.
AMPHIBIA—*Cont.*			
Limnerpeton modestum Fr	N	....	....
obtusatum Fr	N	....	....
Loxoma bohemicum Fr	N	....	....
Macromerion abbreviatum Fr	K	....	....
bayeri Fr	N	....	....
bicolor Fr	K	....	....
juvenile Fr	K	....	....
pauperium Fr	K	....	....
schwartzenbergeri Fr	K	....	....
simplex Fr	K	....	....
Melanerpeton fallax Fr	....	×	×
pulcherimum Fr	....	×	....
pusillum Fr	....	×	....
Microbrachis branchiophorous Fr	N	....	....
mollis Fr	N	....	....
pelekani Fr	N	....	....
Nummulosaurus (Molgophis) kolbei Fr	N	....	....
Nyrania trachystomata Fr	N	....	....
Ophiderpeton corvini Fr	K	....	....
forte Fr	N	....	....
granulosum Fr	N	....	....
pectinatum Fr	N	....	....
persuadens Fr	N	....	....
vicinum Fr	K	....	....
zieglerianum Fr	K	....	....
Orthocosta (Orthopleurosaurus) microscopica Fr	N	....	....
Paleosiren beinerti Gein	....	×	....
? Prorierpeton nitens Fr	K	....	....
Ptyonius ?bendai Fr	N	....	....
distinctus Fr	N	....	....
Ricnodon copei Fr	N	....	....
dispersus Fr	N	....	....
trachylepis Fr	N	....	....
Scincosaurus (Ceraterpeton) gigas Fr	K	....	....
crassus Fr	N	....	....
Sclerocephalus credneri Fr	N	×	....
?latirostris Fr	....	×	....
Seeleya pusilla Fr	N	....	....
Sparagmites lacertina Fr	N	....	....
Sparodus (Batrachocephalus) validus Fr	N	....	....
crassidens Fr	K	....	....
Urocordylus scalaris Fr	N	....	....
REPTILIA:			
Edaphosaurus (Naosaurus) mirabilis Fr	K	....	....
Sphenosaurus sternbergeri Fitz	....	×	....
Solenodonsaurus janeschi Broili	N	....	....
FOOTPRINTS:			
Aciabates sphaerodactylum (Pabst)	....	×	....
Gampsodactylum albendorfensis (Pabst)	....	×	....
Saurichnites perlatus Fr	....	×	....
rittlerianus Hochst	....	×	....
salamandroides Gein	....	×	....
INVERTEBRATES:			
Anthracosia	....	....	....
Estheria cyanella Fr	K	....	....
tenella Fr	N	....	....
Cypridae	....	×	....

CHAPTER V

SUMMARY DESCRIPTION OF THE PERMO-CARBONIFEROUS AND PERMIAN IN FRANCE AND THE SOUTHERN BORDER OF THE HERCYNIAN CHAIN

The structure and stratigraphic relationships of the late paleozoic deposits of central France have not been entirely satisfactorily deciphered. From the various accounts and suggestions made by the many writers upon the subject it is possible to compose a fairly accurate picture of the conditions in various areas, but the fundamental environmental factors and the exact sequence of events are not determinable for all regions. It is altogether probable that the history is a matter of isolated and in part sequent events which have been different in different and sometime closely adjacent areas.

De Launay, in his most valuable *Géologie de la France*, represents the general concensus when he places the Hercynian folding as the fundamental determining event of the late paleozoic. With this idea in mind not only can the relationship of France to Great Britain and the eastern portion of Europe be made out, but an explanation is afforded for much of the discrete and complicated history of the various areas.

If we consider a general map of the trends of the Hercynian folds, as shown in figure 1, we find that there is a general direction from east to west, with a sharp southward convexity of some of the folds over central France. The folds are obscured in many places by the presence of later deposits and have been complicated by later movements, notably the folding of the Alps in Tertiary time. The obscuration thus produced has been the cause of the various conflicting interpretations and the major difficulty in unraveling the history.

The Hercynian system of folds regarded in a broad way are not complicated, but any attempt to understand them more fully reveals that the matter is far from simple. The sketch map (fig. 7), taken from De Launay, shows the integral parts of the seemingly simple whole; they are—

1. A set of folds north of the Central Plateau with a fairly direct east-west trend, but with some slight bending to the south in the central portion. These folds are continuous under the younger deposits of the Paris basin.

2. A set of folds which run northeast-southwest, visible on the eastern side of the Central Plateau and probably continuous under the younger deposits of the Rhone Valley, as folds with similar direction and facies of deposits appear in the Vosges and the Black Forest.

3. A set of folds running northwest-southeast, visible on the western and southwestern side of the Central Plateau; these are much less definitely marked than the series mentioned above, but are traceable into Brittany and into Great Britain. There is not complete agreement upon the details of these folds, nor upon their relation to each other and to other features.

4. A series of Stephanian basins in the Central Plateau whose position is evidently determined by a series of folds or faults running in an essentially north-south direction.

5. A series of folds and basins on the southern and southeastern border of the Plateau which are essentially east and west in direction; these may be considered as the meeting of the two sets on either side of the Plateau and even as a continuation of them, uniting the parts into one continuous whole.

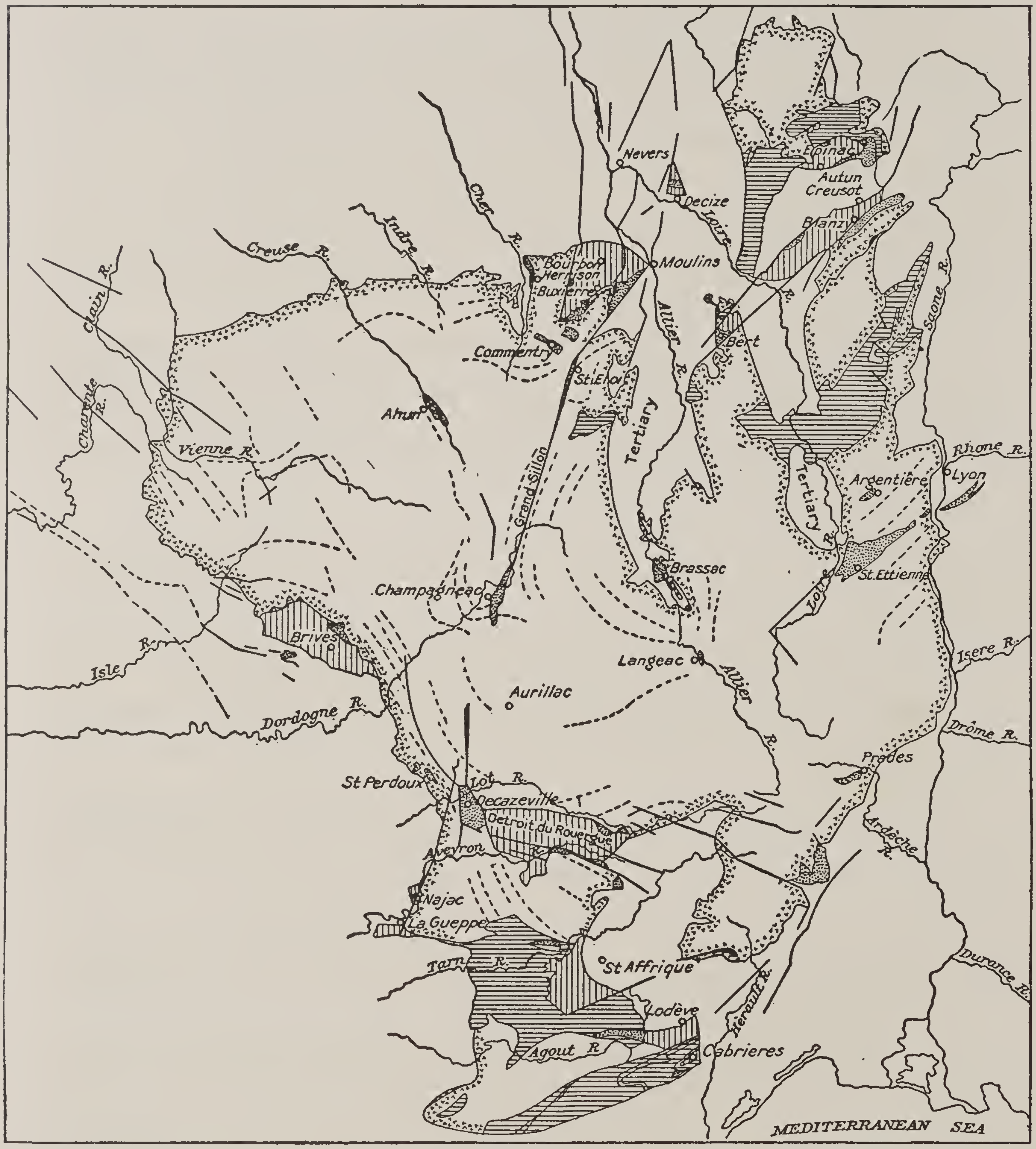

FIG. 7.—Sketch map of Central Plateau region of France, showing direction of Hercynian foldings and location of main basins. After De Launay.

In any attempt to understand the folds and the basins genetically connected with them, it is essential to remember that the sediments of the basins reveal that there were three periods of orogenic movement during the time of their formation and filling, and that the whole region was further distorted by the Alpine folding of much more recent time.

The three periods of movement during the time of formation and filling of the basins, i. e., from Westphalian time to late Permian time, were—

1. The great Hercynian movement which began in Dinantian time and extended into Stephanian.
2. A period of folding at the close of Stephanian time.
3. A period of folding in Mid-Permian time, between Autunian and Saxonian.

The movements between Permian and Triassic time and the great movement of the Alpine folding have complicated the interpretation of the history but may be excluded from consideration in the history of the time interval here discussed. De Launay considers that the movements in late Stephanian and in Permian time can best be considered as the final effects of the Hercynian movement and that they recurred with decreasing intensity. It is further to be noted and kept in mind that these movements were progressive from south to north, probably, as Delafond has suggested (1919–1920), as crumpling movements against the western half of the Central Massif which acted as a buckler, and that the effect upon different basins was a progressive one, so that similar effects in different areas were not synchronous.

From the mass of observations collected and set forth in the very extensive literature, the following statements may be assembled as theses upon which to base the discussion:

1. The northernmost folds of the Hercynian system, running essentially east and west from the northern portion of England along the Franco-Belgian border and into the Palatinate, are Dinantian in age. The depressions were filled by marine waters of Westphalian age, as shown by the fossils contained in the limestones.

The more southern of these folds bend somewhat to the south and are continuous under the Paris Basin. The Central Plateau seems at this time to have been a series of islands in the Westphalian Sea. Deposition during the Westphalian was quiet and there was no mountain making, but apparently a uniform uplifting of the Central Plateau region which forced the draining off of the marine waters and the formation of freshwater swamps in which a considerable vegetation found a place. This upward movement culminated in a real orogenic movement as the Stephanian developed, and the basins were filled with detrital material in the form of swamp, lake and alluvial delta deposits. These deposits have been very seriously affected by later movements so that the coal beds are highly complicated in structure.

2. The conditions in the southeastern portion of the folds are decidedly different from those along the Franco-Belgian border. The Stephanian here lies conformably upon the Westphalian and is covered by the transgressive Saxonian. It was a continuous area of deposition, probably in a depression which developed as the load was delivered into it.

3. As there are no Westphalian deposits in the Central Plateau it is altogether probable that the region was elevated during much of Stephanian time and that the Westphalian deposits have been removed by the erosion of the exposed surface. The accumulations in the synclinal basins on the borders of the Plateau are detrital, of coarse grain in

the beginning and with decreasing size of the grains as the Permian developed. The movement which produced this result was progressive from south to north, it reached the Franco-Belgian border in Stephanian time and involved the coal beds there; the volcanic activity which followed was also progressive from south to north, it reached the Saar region and the Vosges only by mid-Permian time.

4. The Central Plateau was a land area from at least the end of Westphalian time to the end of the Paleozoic. Delafond regards the western portion of the Plateau, Limousin and Marche, as a resistant buckler or shield, comparable to the bucklers of Scandinavia and Africa; the eastern half was more mobile as is witnessed by the more pronounced and continuous depressions of Autun-Epinac and Blanzy-Bert.

All writers upon the Paleozoic deposits of the Central Plateau are in essential agreement that the direction of the basins is governed by the direction of the Hercynian (Variscan and Armorican) folds. The apparent divergences from these directions, as in the Grand Sillon, are modifications due to secondary causes.

It is not within the province of this paper to discuss the tectonics of the Central Massif of France. The reader interested in this subject can follow it in the voluminous literature of the French geologists. It is enough to state that from the various discussions and polemics on the subject it is apparent that the topography of the central region was governed during a part of Westphalian and all of Stephanian and Permian time by the Hercynian folds, and that the apparent divergences from the directions induced by these folds are due to explainable secondary causes. It was the nature of the topography, with its possibilities of oriented basins and their possible connections or separations, which governed the distribution and development of life during the periods discussed.

General pictures of the Central Plateau in the closing periods of the Paleozoic are given by several authors.

Delafond (1919–1920) says that the coal was deposited in large basins which were deformed at the end of the Stephanian [but not enough to prevent continued deposition in some of them—The author], and new basins were formed in the Permian in approximately the same places. The smaller depressions were destroyed in the Stephanian movements. The sediments of the basins at Autun, Blanzy, Creusot, and some in the Allier (Buxière and St. Hiaire) show the same thing between the Autunian and the Saxonian.

Delapparent (1906, page 896) pictures the region after the Dinantian as an elevated area, covered with an abundant and vigorous vegetation, the debris of which was swept into the heads of estuaries formed by torrential streams. The lakes into which the streams entered were sometimes isolated and sometimes arranged in series along the depressions formed by the Hercynian folds. The Stephanian was a time of continued elevation which permitted the rapid accumulation of coarse debris through a long period of time. In the Autunian the presence of small fragments of coal in the conglomerates indicates the destruction of Stephanian deposits. By Mid-Permian (Saxonian) there began the series of volcanic outbursts which contributed so much lava and clastic material of igneous origin to the deposits. The early Permian was, in places, little differentiated from the late Stephanian and the old basins remained the site of continuous sedimentation and the accumulation of volcanic material.

Michel-Levy (1907–1908, page 276) says that during the Stephanian and Permian there was intense degradation of the Plateau which was covered by a luxuriant vegetation induced by a warm humid climate. He speaks of two kinds of accumulating areas:

1. Synclinal basins parallel to the Hercynian chain as at Sincy, St. Foix, Argentiere, Autun and Blanzy-Bert.
2. Narrow areas due to fractures of the Hercynian chain as at Vallie de Azerques.

De Launay speaks of the Stephanian deposits as having been formed in place in the beds of lakes. These lakes are not to be regarded rigorously as of synclinal origin but perhaps of a more accidental inception. The original deposits were probably much larger than they appear today, the original extent having been reduced by folding and by the erosion of the peripheral portions. All the Stephanian deposits show much complication and folding due to the post-Stephanian movements; at St. Eloy the portion preserved has been reduced to one-third of its original volume by folding. It is apparent that the folding movement was not synchronous in all the basins, as some of the Stephanian deposits are folded and others were formed in basins produced by the folding. The folding and displacement was the result of progressive movements which advanced from the southeast to the northwest so that the basins at St. Ettienne and Rive-de-Gier were filled earlier than those of the central portion of the Plateau, and the latter earlier than the basins at Sincy, Decize, Commentry, and Autun, which in turn preceded those at Buxière and Bert. It must be noted that all of the French geologists recognize that the Central Plateau suffered profound degradation in the process of filling the Stephanian and Permian Basins and that though the inception of the basins lay in the Hercynian folding there was a considerable degree of independence in the movements of the waters as the lakes expanded over the leveling surface. De Launay compares the condition of the surface during the Stephanian and Westphalian time to the Karroo district of southern Africa which was too high for the accumulation of marine deposits but was subject to vertical oscillations and to slight folding, a condition which permitted the accumulation of sandy and argillaceous material and the formation of shallow basins in which water and carbonaceous material could concentrate.

During Permian time the Plateau was still an emerged region, but the process of degradation had so lowered its surface that there was a decided transgression of the waters over the surface. This process began in the east and advanced toward the west, a movement which was continued after the Permian into the Triassic and Liassic, when it was terminated by a renewal of the upward movement.

The slowly subsiding disturbance of the late Stephanian made itself felt through the Permian with ever-decreasing intensity, so that toward the end there were only slow and very broad movements, permitting the formation of large lagoons, abundant plant growth and the accumulation of very fine sediments in the quiet waters.

It is to be noted that the French geologists very distinctly recognize a progressive movement of the orogenic and volcanic forces in the Central Plateau—a progressive movement that must have carried with it a progressive change in the environmental conditions of the fauna and the flora. This is just such a progressive change as the author has attempted to establish for the Permian period in the North American Continent (Case, 1919), and as is noted for the Schwarzwald by Hennig (1923).

It is obvious from the above citations that many of the Stephanian basins of the Central Plateau are directly connected with the Permian basins, in origin and sequence. In some there is no unconformity between the deposits of the two periods; the Lower Stephanian is decidedly different from the Permian in fauna and flora but there is frequently great difficulty in distinguishing between the Upper Stephanian and the Permian. This is one of the factors which has made it so difficult to evaluate the deposits and environmental conditions of the two periods. In order to place the evidence before the reader in as clear a manner as possible the basins of the Stephanian and Permian will be considered in three groups:

1. The basins of Autun-Epinac and Creusot-Blanzy. These are distinctly synclinal basins oriented with the similar basins in the Vosges and the Black Forest.
2. A series of basins on the eastern, southern and southwestern borders of the Plateau, beginning on the east with St. Etienne and continuing around the Montagne Noire, Rouergue and Cévennes, through Decaizeville to, and beyond, Brives.
3. The series of basins more or less perfectly oriented north and south, which lie along the Grand Sillon from Moulins to Najac, and certain basins in the valleys of the Loire and the Allier.

Such a grouping would not be acceptable to all French geologists, but as they are not agreed among themselves, and as the idea in using such a classification is simply to give a clear idea of the position of the basins and the conditions surrounding the life of the period, it seems the most usable.

SUMMARY DESCRIPTIONS OF THE VARIOUS BASINS

The following description of the basin of Autun-Epinac is largely drawn from the report by Delafond (1889) upon the stratigraphy of the area.

There are three stages of the Carboniferous represented:

3. Stage of carbonaceous material of Moloy.
2. Stage of barren sands and conglomerates.
1. Stage of shales and coal of Epinac.

The lowest stage, shown at Epinac, is variable in the composition of the beds, but is essentially an accumulation of sandstone and shale with a subordinate amount of coal. The coal beds are irregular in position and form and are equally irregular in thickness. The plants found in relation with the coal indicate an age between that of the beds at St. Ettienne and the beds at Rive de Gier.

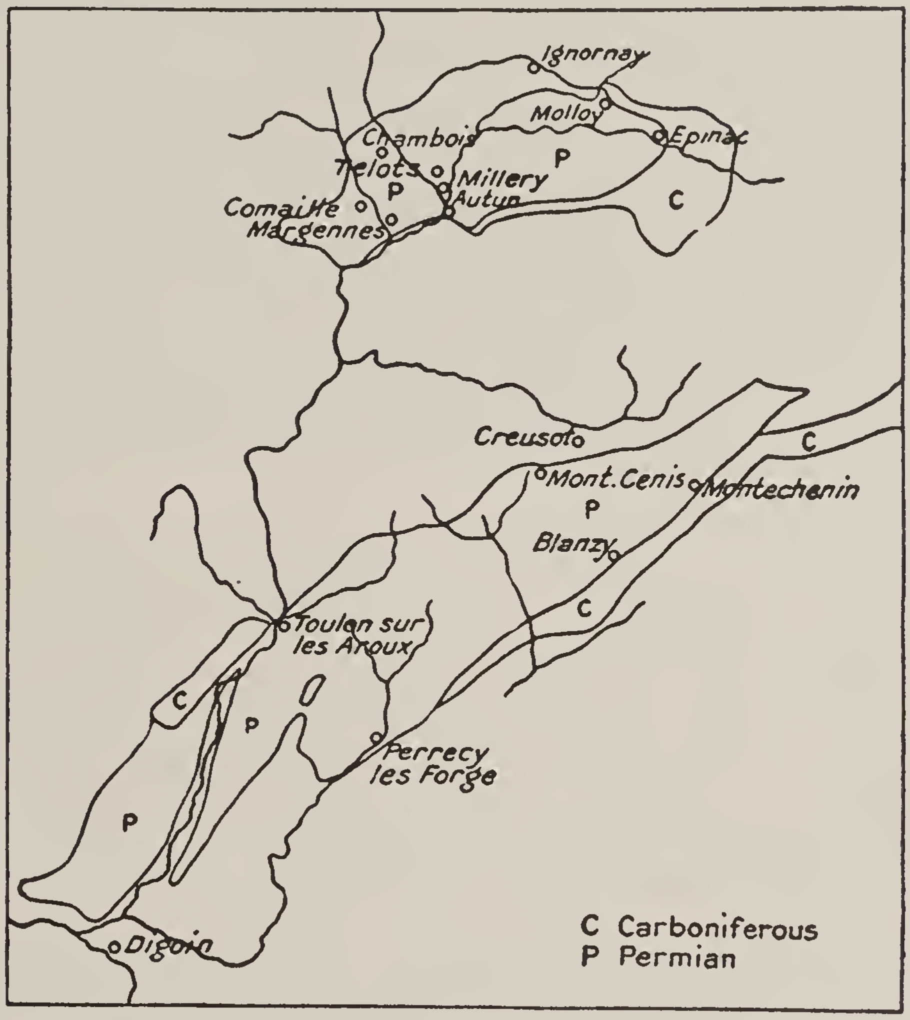

FIG. 8.—Sketch map of basins of Autun-Epinac and Blanzy-Creusot.

The beds of stage 2 show an alternation of sandstones and conglomerates with some rare shales and thin veins of coal. The beds of this stage are not the same on the north side of the basin as on the south side. On the south side the conglomerates are made up of fragments of granite, some of enormous size, several meters, and hardly rounded. On the northern side the conglomerates are less abundant and the fragments are much smaller; the material is essentially porphyritic, fine grained and with frequent beds of shale. This stage is shown only in the eastern part of the basin and disappears toward the north at Sully; it is especially strong on the southern border of the basin. Plants are known only from the upper portion and closely resemble those of the next stage above.

The beds of the third stage are generally fine-grained sandstone, with rare conglomerates and some shales. There are a few thin and irregular seams of coal. The beds of this stage show as a nearly complete ring around the Permian deposits of the Autun Basin. In the east they lie upon the beds of the middle zone, but toward the west they lie on older formations. The flora is of the uppermost Carboniferous, the zone of Calamodendrons.

The Permian is divided into two stages:

II. The red sands.
I. The bituminous shales.

The lower of these two stages, the bituminous shales, is much like the Carboniferous in character with much sandstone, conglomerate and shale. It is described as existing in three sub-stages:

3. The sub-stage of Millery. This is dominantly shaly with one bed of bituminous shale and one of bog-head coal. De Lapperent includes in this sub-stage the red sandstone above, which is regarded by other writers (as Delafond) as representing a distinct stage.

2. The sub-stage of Comaille-Chambois. This is dominantly sandstone. At the base are bituminous shales, including the Grand Couche; in the middle and upper portions are barren sandstones with thin seams of coal and one bed of coal.

1. The lowest of the sub-stages, that of Igornay-Lally, worked also at St. Leger-du-Bois, is a strong series of sandstones and conglomerates which enclose only two beds of bituminous shale. The occurrence is somewhat different at the two places.

At Igornay most of the beds are shales with some bituminous shales which afford oil by distillation. In two localities there are thin beds of dolomitic limestone which have afforded shells of fresh-water forms, probably *Cypris*. Beds equivalent to these have been found at Dinay, Lally, and near Autun. These beds rest conformably upon the older deposits; they are replaced by sandstone toward the west and south. At Lally the beds are largely sandstones and conglomerates. There is a single bed of bituminous shale between the upper sandstones.

The flora of these two areas is largely Carboniferous but, as *Callipteris* has appeared, De Lapparent regards it as a transition stage; Delafond gives the following list of the most characteristic forms:

Callipteris (rare but appearing at Igornay).
Callipteridium rochei.
Neuropteris planchardi Zeill.
Sigillaria spinulosa = S. brardi Brgn.
    brardi Brgn.
Syringodendron pescapre Strnb.
    alternans Strnb.
Stigmaria ficoides Brgn.
Sphenozamites rochei Renault.
Cardiocarpus.
Pachytesta gigantea G. E.
    crassa (? incrassata Zeill.)
Trigonocarpus.
Polypterospermum.
Codonospermum.

The last six are especially abundant.

The fauna of Igornay-Lally is as follows:

Pisces:
    Acanthodes bronni Ag.
    Amblypterus duvernoyi Ag.
        gaudryi Sauv.
        rochei Sauv.
    Megapleuron (? Sagenodus) rochei Gaud.
    Paleoniscus angustus Ag.
    (Amblypterus) blainvillei Ag.
    (Amblypterus) voltzi Ag.
    Pleuracanthus bonnardi Ag.
    Radianicthys ? lalleyi Sauv.
Amphibia:
    Actinodon frossardi Gaud.
    Euchirosaurus rochei Gaud.
    Pelosaurus laticeps Cred.
    Protriton (Branchiosaurus) petrolei Gaud.
    Sauravus cambrayi Th.
Reptilia:
    Stereorhachis dominans B & G.
Invertebrates:
    Cyprioides.
    Nectotelson rochei Brocchi.

This fauna is the same as that found in the bituminous shale of the Autun region and is absent from the upper Carboniferous.

2. The middle sub-stage of the lower Permian, Stage of Comaille-Chambois, sometimes called the shales of Muse, is widely represented in the basin of Autun, but some parts are limited in extent. Four main divisions are represented, comprising a thickness of 300 to 500 meters:

d. A bed of coal at Chambois.
c. A series of bituminous shales.
b. A series of alternating sandstones and shales with the sandstone dominant.
a. A bed of bituminous shale, the Grand Couche.

In the division *c* there is a bed of magnesian limestone at Comaille with a few indistinct fossils, probably *Cypris.* At Chambois there is a layer of kidney-shaped calcareous nodules along the bedding plane of the shales. At Igornay there is a limestone probably equivalent to these beds. Much silicified wood occurs at this level.

In the division *a*, the Grand Couche, the succession of layers is pretty generally as follows:

	Meters
Bituminous shale	0. 7–0.8
White clay parting	.03– .06
Bituminous shale	.27– .30
White clay parting	.01–
Bituminous shale	0.65–0.90
White clay parting	.01–
Bituminous shale	.75–1.20
Barren shale	.05– .15

This bed is limited to the region of Comaille, Chambois, and Dracy-St. Loup.

The characteristic forms of the flora as given by Delafond for this stage are as follows:

- Callipteris conferta Strnbg.
  - lyratifolia Goepp.
  - naumanni Gutb.
  - praelongata Renault.
- Odontopteris schlotheimi (rare) Brgn.
- Pecopteris arborescens Schlth.
  - cyathea (= arborescens).
- Annularia stellata Schlth.
- Calamites suckowi Brgn.
- Macrostachys infundibuliformis Brgn.
- Sigillaria brardi Brgn.
  - menardi (= brardi).
- Codonospermum anomalus Brgn.
  - minus Brgn.
- Cardiocarpus.
- Trigonocarpus.

The fauna of Comaille, Chambois, and Dracy-St. Loup:

PISCES:
- Acanthodes bronni Ag.
- Amblypterus inaequilobum Blv.
- Paleoniscus (Amblypterus) blainvillei Ag.
  - angustus Ag.
  - (Amblypterus) voltzi Ag.
- Pleuracanthus bonnardi Ag.

AMPHIBIA:
- Actinodon frossardi Gaud.
- Actinodon brevis Gaud.
  - ? major Gaud.
- Euchirosaurus rochei Gaud.
- Pelosaurus laticeps Cred.
- Protriton (Branchiosaurus) petrolei Gaud.

INVERTEBRATES:
- Cyproides.
- Dendropupa walchiarum (Fischer).

According to Thevenin *Actionodon brevis* and *Euchirosaurus* are but growth stages of *Actinodon frossardi.*

3 The uppermost sub-stage of the lower Permian, Stage of Millery, is dominantly shale with a few intercalated beds of fine sandstone. There are a few thin beds of bituminous shale and one of Bog-head coal. There is also a thin bed of limestone. Some of the shales above the Bog-head contain silicified nodules; the whole series is rich in silicified wood. The Bog-head coal plays out laterally, much resembling in this respect the bed of Cannel coal at Linton, Ohio, and suggesting its formation in a similar pool. De Lapperent includes in this division the red sands, or Stage II of Delafond.

The characteristic forms of the flora are given by Delafond as:

Callipteris juteri Zeill.
    obliqua (= C. conferta).
    pellati Zeill.
Linopteris (Dictyopteris) schutzi (Roemer).
Odontopteris schlotheimi Brgn.
Taeniopteris multinervis Weiss.
Asterophyllites (= Calamites).
Calamites gigas Brgn.
Strobilites (Cycadospadis) milleryensis (Renault).
Walchia imbricata Schimp.
    taxinoides.

De Lapperent says that this is a true Permian flora; Haug says that with *Callipteris conferta* and *Walchia piniformis* it is dominantly Permian.

Fauna of Millery:

Pisces:
  Amblypterus baleyi Sauv.
      beaumonti Edgerton.
      bertheri Sauv.
      duvernoyi Ag.
      gaudryi Sauv.
      inaequilobum Blv.
      reussi Heckel.
      levyi Sauv.
      rochei Sauv.
  Cheiracanthus sp.
  Paleoniscus angustus Ag.
  (Amblypterus) blainvillei Ag.
Pisces—Cont.:
  (Amblypterus) longissimum Ag.
  (Amblypterus) voltzi Ag.
Amphibia:
  Actinodon frossardi Gaud.
  Protriton (Branchiosaurus) petrolei Gaud.
  Sauravus cambrayi Th.
Reptilia:
  Callibrachion gaudryi B and G.
  Haptodus baleyi Gaud.
Invertebrates:
  Cyproides.
  Nectotelson rochei Brocchi.

The Upper Permian, Red Sands, occur in the center of the Autun Basin. They are represented by sandstones and shales which have the same red or red-brown color found in the equivalent horizon in the Blanzy-Creusot Basin. They are unconformable on the Lower Permian as is shown at various localities. The beds have yielded no traces of plants or animal remains.

In the opinion of Delafond this basin was of continuous growth during the Stephanian and Permian, partly through orogenic movement and partly through a sinking due to the accumulating weight of the sediments. The accumulation of the coarse sands of the upper stage was due to an elevation, at the close of the lower Permian or continuous all through the Permian.

Basin of Blanzy-Creusot

This basin is elongate in the direction of the Variscan folds and is parallel to the basin of Autun-Epinac. It is made up of two smaller basins, also elongate and parallel to each other and to the long axis of the basin as a whole. These depressions are but a part of a much larger one which was originated in Stephanian time. The original depression was filled by a more or less disordered mass of Stephanian material which appears to have been swept in rather than deposited in place. At the close of the Stephanian the basin was folded and in part excavated by river erosion and the two smaller basins, Blanzy and Creusot, were formed. The material of Permian age was accumulated in the double depression which is in part tectonic and in part erosional in nature. Figure 9 gives the present idea of the structure and formation of the basins and the deposits. A third smaller depression at Forges is apparently of the same origin and has the same history as the larger basins.

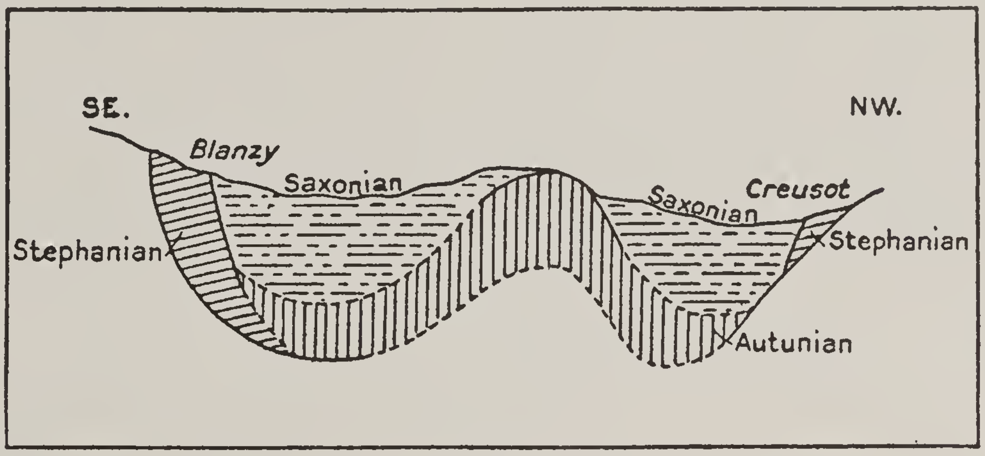

FIG. 9.—Cross-section of Blanzy-Creusot Basin.

It is apparent that there were two periods of folding and erosion and two periods of filling. At the close of the Stephanian there was distortion of the Stephanian beds and some river erosion; the basin was filled or partially filled with Autunian and a second distortion at the close of the Autunian with accompanying erosion by streams, then the depressions were occupied by Saxonian deposits. Later distortions have further obscured the original relations of the beds but these are not shown in the sketch.

The Autunian lies unconformably upon the Stephanian, but this is not the result of faulting as supposed by earlier writers, but of the distortion of the Stephanian and of river erosion of the older beds before the Autunian was deposited.

The nature of the Autunian is shown by outcrops at various places and by borings. The lower part of the formation is, as in the region of Autun, dominantly sandstone and conglomerate with the upper part much more shaly. At Charmoy there is a very fine-grained shale, highly micaceous and blackish or yellow-gray in color. There are some thin beds of dolomitic limestone and thin seams of coal. A boring at this place shows the upper 480 meters to be largely shale, below this the sands are more abundant and the elements of the conglomerates become larger; sometimes a true arkose can be recognized. At 900 meters the boring passed from Autunian directly into the granite. The shales at Charmoy contain no productive coal seams, no Bog-head and no bituminous shale. At the pond of the village of Martenet, at Le Puits, and at Vandesse-sur-Arroux, all small places, there are exposures of black or chocolate-brown shale, sometimes micaceous, carrying imprints of *Walchia*.

The Lower Saxonian covers large areas in the basin and shows very different facies in different localities; all are, however, similar in a general way. There are many beds of clay, of varied color, black, red, green and chocolate brown, alternating with sandstones and arkoses.

On the road from Mount Cenis to Toulon-sur-Arroux there are exposures of arkose, especially in the higher places. At Bois-Litteau, west of Charmoy, there is a gray or white sandstone with pebbles of old rocks; here the change from the Autunian to the Lower Saxonian is very sharp. The same white sandstone is seen on the flanks of the Pointins, notably at Loge and Vernes. At Praye there are boulders of granulite three times the size of a human head; at Crot-Monial there are boulders 0.5 meter in diameter. North of Curdon, at the village Chez Buisson, a pit shows a seam of coal 0.02 meter thick at a depth of 11 to 12 meters. Close to the village of Crot a pit passed through two thin coal seams enclosed in a sandstone. South of Sanvignes a pit has yielded numerous imprints of plants.

The Lower Saxonian is generally conglomeratic at the base; this is especially noticeable on the northeastern border of the basin and on the elevation which runs from Mount Cenis to Toulon-sur-Arroux. The conglomerates are generally white or grayish, becoming redder toward the top; in some places it is arkosic, as at Le Couchet, Sanvignes, and Mount Cenis. The few veins of coal and the calcareous layers occur toward the top.

The Upper Saxonian is mostly loose sand, or sandstone, generally red with white bands. Sometimes this red sand is represented by conglomerate with elements of granite, gneiss, granulite, microgranite and ancient schists. Between the villages Fresse and St. Eugene, a section shows coarse red sandstone with white bands; this sand becomes coarser toward St. Eugene, where it is a true conglomerate. Another zone of coarse sandstone lies in the center of the basin along the east flank of the ridge formed of Lower Saxonian, from Mount Cenis to Toulon-sur-Arroux. Near Digoin the sandstone carries some siliceous beds. A typical section taken near Vesvre gives the following:

	Meters.
Fine reddish sandstone with some pebbles (siliceous)	32
Coarser flinty sandstone with rare and thin veins of clay	21
Ordinary red sands	7
Red sandstone with white bands	128
Red and white sandstone with pebbles, the elements sometimes enormous	5
Sands, banded red and white	16
Argillaceous and ferruginous sandstone with some greenish nuculei	9
Banded sandstone	6
Sands with red and green shales, calcareous veins. With trunks or stems of silicified wood	15

This is a very characteristic section of the Upper Saxonian, showing the dominance of the loose sands above and the greater coarseness of the grains below. Below 300 meters appear the red and green shales which mark the beginning of the Lower Saxonian. The silicified wood appears in what is probably a transitional zone and may belong in either divisions of the Saxonian.

The Basins of the Allier[1]

The smaller detached basins to the west of the basins of Autun and Blanzy are in large part covered by deposits of later age and have been seriously deformed by later movements and faulting. It is generally conceded, however, that the basin of Bert is a continuum of the basin of Creusot and it is probable that the basin of Bourbon l'Archimbault has the same relation to the basin of Autun. It is certain that the deposits in these basins once covered much larger areas than at present, especially in the later Permian.

The deposits indicate that during a portion of the time, at least, the smaller basins were broken up into smaller collecting regions or that the conditions of sedimentation were quite different in the different portions. Five series may be recognized in a general way:

5. The red sandstone; thin, red or green, micaceous sands.
4. The arkose of Cosne.
3. The argillaceous sands with much mica.
2. The arkosic sands of Bourbon.
1. The bituminous shales.

In the region of Bourbon l'Archimbault the series is well represented.

1. The bituminous shales are regularly bedded and thin. There is uniformly a dominance of sands at the bottom, changing to a series of bituminous shales and finally to sandstone with included calcareous layers which have frequently been infiltrated with silica. The section of one basin is not identical with that of another; thus in the vicinity of Buxière there is a very different sequence from that near St. Hilaire, a short distance away. This is largely due to the lack of the calcareous and silicified layers at the top and may be in part due to the erosion of the upper part. The flora of this upper part of the series is largely, if not entirely, Stephanian; *Psaronius giganteus* has been identified in the rich flora but the facies is still that of the upper Carboniferous. The fauna contains *Paleonicus*, *Diplodus*, *Icthyodorulites*, *Coprolites*, and some bones of *Actinodon frossardi*.

2. The arkosic sands of Bourbon. These are variegated green, violet and red; sometimes shaly. In a quarry at Coulandon, halfway between Souvigny and Moulin there are pebbles from the adjacent igneous rocks. Three characteristic beds are revealed in the series of alternating arkoses and marls.

3. Tile sandstones, breaking like pottery.
2. Paper shales with impressions of fish.
1. Black or brown calcareous beds, somewhat silicified.

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[1] The description of the Permian of the Allier is largely taken from De Launay (1887–1888).

The flora includes *Callipteris conferta*, *Calamodendron cingenium*, and silicified stems of *Psaronius*. The fish of the paper shales are *Paleoniscus* and *Amblypterus*.

3. The argillaceous, micaceous sands are very unresistant and are exposed only in a locality a little northeast of Bourbon. They are fine grained, greenish, splitting into plates because of the mica and readily crumble between the fingers.

4. The arkose of Cosne is an unevenly bedded mass of variegated sandstone; the color is generally red, mottled with spots of red or yellow on a white ground, or the spots are pure white. The equivalent layer at Commentry has pebbles derived from the adjacent igneous rocks; the sandstone is in general hard with glistening surface and angular grains. In the middle of this series there is a layer of clay which is ordinarily white and usually siliceous. This seems from its occurrence to have been deposited in small isolated lakes but to have been derived from the common degradational area.

A flora found at St. Marie de Montvicq includes:

Calamites suckowi.
Pecopteris polymorpha.
Cordaites.
Annularia longifolia.
Annularia sphenophylloides.

5. This series outcrops in the northern part of the basin, north of Bourbon, in a direction generally parallel to the basins of Autun and Creusot. The material is fine and coarse sandstone of a reddish or brown color.

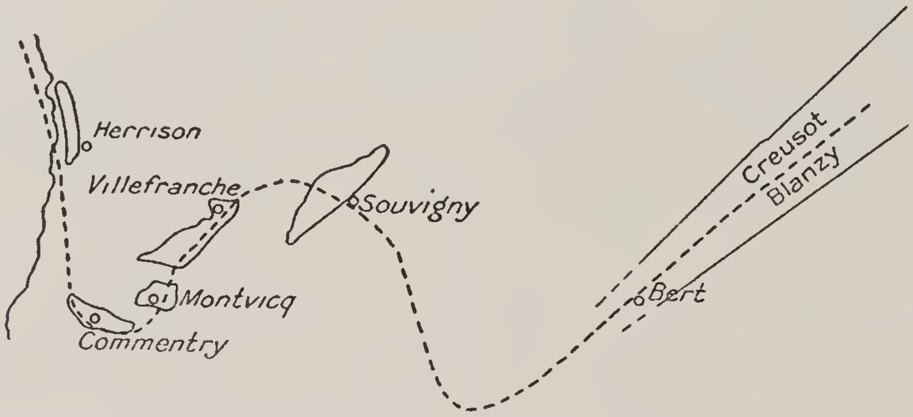

FIG. 10.—Sketch map showing relation of basins of the Grand Silion to those of the Blanzy-Creusot region. After Delafond.

The small basin of Bert is, in all probability, a continuation of the Autun Basin. Only two of the five series described above are present: the Red Sands at the top and a lower series of shales containing rare specimens of *Walchia piniformis*. According to Delafond there is a conglomerate and a coarse sandstone at the bottom. The Permian lies unconformably upon the Stephanian and there has been much disturbance of the beds by later movements.

Sterzel (1893) gives the following list of the flora which he regards as indicating the Lebach age of the beds.

Callipteris praelongata Renault.
Linopteris (Dictyopters) schutzia (Roemer).
Pecopteris densifolia Goep.
  hemiteloides Brgn.
  polymorpha Brgn.
Taeniopteris sp.
Psaronius.
Calamites cisti (leioderma) Brgn.
  cruciatus Strnbg.
Annularia stellata Schlth.
Stachannularia tuberculata Strnbg.
Sphenophyllum cf. oblongifolium Germ.
Stigmaria ficoides Brgn.
Poacordaites palmaeformis Goep.
Walchia piniformis Schlth.
Cardiocarpus triangularis ?
  pediculata ?

A somewhat younger age is indicated by the frequent occurrence of—

Callipteris conferta, many varieties.
Walchia linearifolia Goep.
Cardiocarpus ottonis Gutb.

A few purely Carboniferous forms have been found, as—

Sigillaria brardi Brgn.
  spinulosa = S. brardi.
Syringodendron.
Sigillariostrobus.

The fauna of the region, so far as known, is—

Amblypterus delessi Sauv. from Buxiere.
Acanthodes sp. from Buxiere.
Conchopoma sp. from the Allier.
Elonicthys sp. from the Allier.

Delafond describes the basin of Bert (1919–1920) as having three layers. At the top is a dominantly shaly formation with beds of coal intercalated at three different levels; in the middle a strong formation of sandstone and conglomerate. A lower layer, which is shaly, has a small vein of coal lying on a bed of conglomerate.

The Permain at Decize

This small area of Stephanian and Permian has been so much deformed and so much displaced by faulting that its relation to other regions is quite uncertain, but there seems little reason to doubt that it was formerly much larger and probably had the same general orientation as the better-preserved basins. The Stephanian deposits are deltaic and cut by faults of pre-Permian age. Other faulting occurred after the Permian and Triassic, and still other faults were formed in successive periods, reaching even to the Miocene.

The Permian is separated from the Stephanian by a sharp unconformity, but there is no unconformity between the Permian and the Triassic.

The uppermost beds are the common red sands which occur in the basin of Bourbon l'Archimbault. Below is a series of greenish shales which contain the following flora as identified by Zeiller.

Callipteris conferta permiana Brogn.
  gigantea Brgn.
  praelonga Weiss.
Pecopteris unita Brgn.
  annularia?
Bruckmania tuberculata Sternb. (tip of Calamite).
phenopteris cf. decheni Weiss.
  cf. leibachesis Weiss.
  cf. odorata Weiss.
Walchia filiciformis Sternb.
Cordaites.

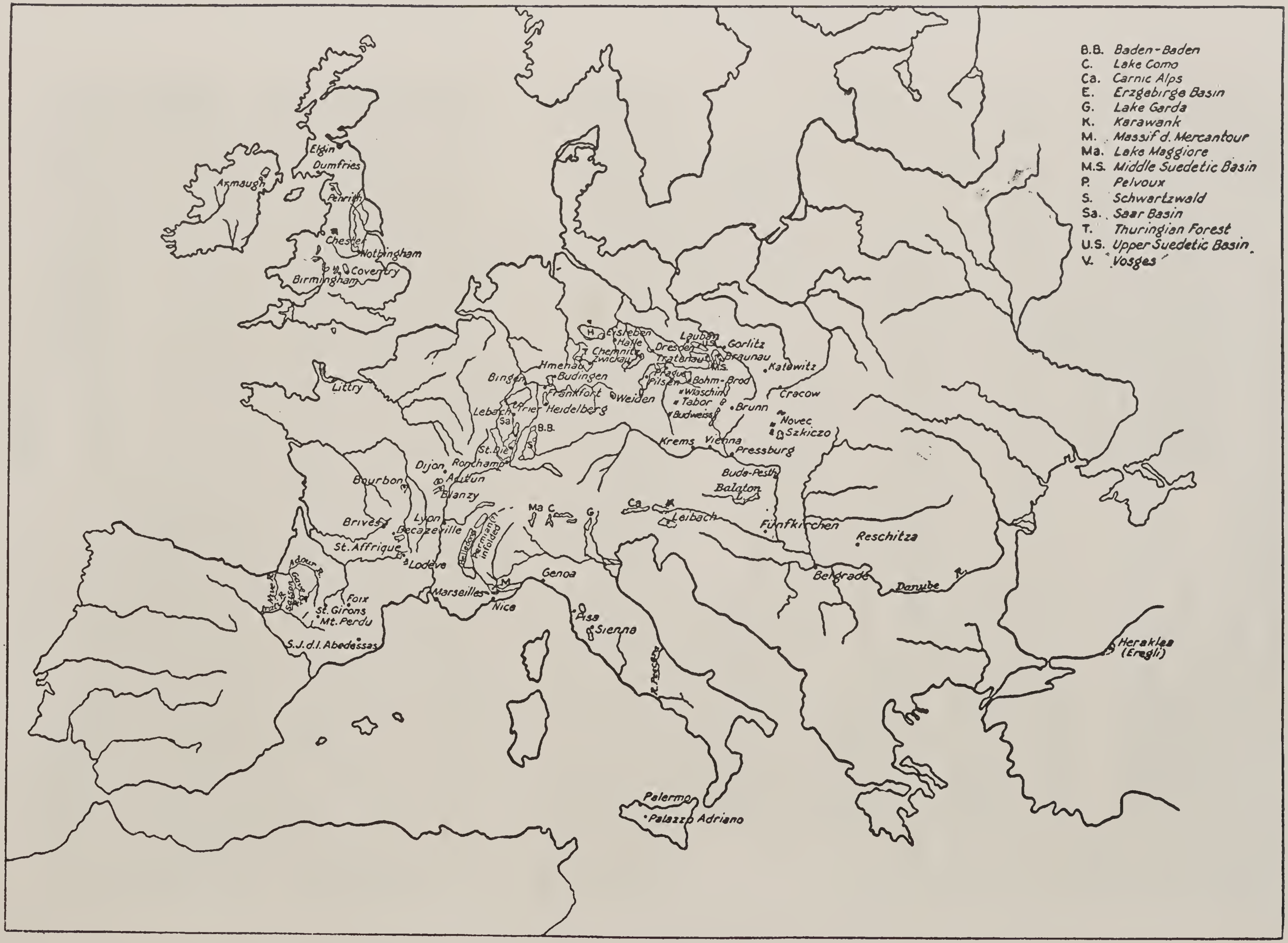

FIG. 11 —Sketch map of central and western Europe showing general relation of regions mentioned.

AREAS OF PERMIAN ON THE SOUTHERN AND SOUTHEASTERN SIDES OF THE CENTRAL PLATEAU

On the southern side of the Plateau the basins are oriented nearly east and west in conformity with the direction of the old Hercynian folds at the lower part of the great southern curve, where the Variscan and Armorican portions meet.

There are three areas in succession from north to south; the first is the Détroit du Rouergue between the Hercynian massifs of Aubrac and Ségala, its general outline being marked by the position of the coal deposits at Decaizeville, St. Geniez and Gages. To the south of this lies the second area, in the neighborhood of St. Affrique, bordered on the north by the coal deposits at Brousse and probably extending to the east under younger deposits, to reappear in the region of Le Vigan. The third area is in the region of Lodève with the coal deposits of Graissessac.

De Launay, in his *Géologie de la France*, p. 165, says of this region that there are three divisions of the Permian which are generally present:

3. Thuringian. Red shore deposits with ripple marks.
2. Saxonian. Red sandstones and shales.
1. Autunian. Black bituminous shale.

In presenting the history of this portion of the Permian of France, De Launay states that these areas of sedimentation originated in depressions of the Hercynian folding, and these were filled with deposits of the Stephanian and Permian. The intensity of the folding which occurred during Stephanian time was gradually reduced through the Permian, the basins were filled, and the waters flooded far beyond the original borders. The Permian is always transgressive upon the Stephanian and De Launay considers that even by Saxonian time the Permian covered the area between Rodez and Najac. From the nature of the progressive change in the sediments with the passage of time he considers that the Plateau was pretty well peneplainized by early Permian time and that perhaps the waters extended very widely over much of the upland surface.

The sequence of the beds in the different basins is not the same, but the lowest beds, Autunian, are conformable upon the Stephanian, whatever their nature. In the Détroit de Rouergue, De Launay describes the common lower beds as bituminous black shale. Haug, writing of the same general region, the valley of the lower Aveyron, describes the beds as beginning with conglomerates of limestone, dolomite and jasper, above which are dark-colored shales with *Walchia*. Fabre reports the same condition. Thevinin (1902–1903) gives the basal series as beds of gray, fissile sandstone and shale shading insensibly in to the Stephanian, but says that the shales are sometimes absent and that sometimes there are lenses or conglomerates of calcareous material.

The Saxonian in the Rouergue is given by Thevinin as follows:

3. Fine sandstone intensely red with intercalations of calcareous material.
2. Clay, sometimes with lentils of calcareous matter carrying impressions of plants.
1. Coarse sandstone and heavy conglomerate.

This sequence is not all shown in the same section. The Saxonian was transgressive on the Autunian and the original limits are not now determinable, partly because of subsequent erosion and partly because the edges of the exposures are marked by faults. As the beds are almost entirely devoid of fossils the determination is largely by analogy with other regions.

Mouret (1891) gives the following sequence as obtaining in all of the beds on the south side of the Central Plateau:

5. Red sandstone.
4. Sands and shales with *Walchia*.
3. Limestones and shales with fish remains.
2. Lower red sands and upper coal sands.
1. Older coal sands.

The first two of these are undoubtedly Stephanian in age. The third and fourth are not exactly synchronous in all places and are variable in thickness, but indicate a similarity of conditions when deposited. The red sands were deposited in quiet water as indicated by the nature of the beds, and the absence of plant remains is rather due to their destruction than to the presence of rapid water as suggested by Bergeron. The red sands of the Aveyron and of the Tarn are shown in the basins of Rodez, St. Affrique, Cordes, and Lodève, and they reach a thickness of 500 to 600 meters with almost the same facies of red sandstones and shales in all places. The red sands are always conformable on the beds carrying fish and *Walchia* remains, and the transition from one to the other is gradual; in only one place, Neffiez, is there a bed of conglomerate, 10 meters thick, between the two. The lower part of the red sands is dominantly sand but changes to dominant clay with occasional beds of white sand; the grain becomes increasingly finer toward the top. The red sands are transgressive beyond the shales and when traced toward their origin become coarser in grain and even conglomeratic.

Fauna:
  Amblypterus rohanni Ag, Decaizeville,
      arcuatus Eger, Decaizeville,
  Acanthodes sp. Decaizeville.
  Amblypterus duvernoyi Ag, Lodève,

M. Mouret gives the following series of the beds at Brives on the western side of the Central Plateau:

Upper red sands:
  7. Sands of the Ramiere.
  6. Sands of Meyssac.
  5. Sands of Grammont.
  4. Red sands and clays of Brives.

Beds with *Walchia* and fish:
- 3. Sands with *Walchia*.
- 2. Limestone of St. Antoine.

Permo-carboniferous;
- 1. Lower red sands and coal sands.

The sands of bed No. 1 are reddish and not variegated, white or gray, fine grained and, generally, more or less ferruginous, compact and sandy. The shales are gray, blackish or black, fine or coarse grained (the coarser grained dominant). The fine-grained shales are always blackish. These are transition beds, containing a flora of the uppermost Stephanian (Grand 'Eury's zone of *Calamodendron*), with some Permian forms. The gray sands and shales of beds 2 and 3 are true Permian, facies of Autun. They are often more fine grained than in bed 1 and are often micaceous, slaty in texture, and well bedded. The color is grayish yellow or grayish green, never black and compact. The flora is a true Permian flora and there are remains of fish in the shale beds intercalated in the limestone. The calcareous layers in bed No. 2 are blackish, rose-colored or greenish, massive or bedded; sometimes with nodular layers. The calcareous material may extend into the beds on either side. The calcareous beds are not constant in other basins, they may be absent or much reduced in importance. On the eastern and southeastern sides of the basin the calcareous matter is more pure and constant in its occurrence, on the northwest it is more argillaceous and nodular; in the western part the calcareous matter and even the clay disappears. The sands with *Walchia* are compact, frequently coarse grained and even with pebbles. The color is gray, gray-yellow, gray-green or yellowish. Only at the top is it red or variegated. Intercalated with the sands are shaly or clayey layers which are generally thin. The bituminous shales are of small importance and the calcareous beds occur only near the top.

The floral list given by Zeiller is as follows:

- Callipteris conferta Sternb.
  - curretiensis Zeill.
  - diabolica Zeill.
  - naumanni Gutb.
  - subauriculata Weiss.
- Linopteris (Dictyopteris) schutzi ?? (Roemer).
- Pecopteris dentata Brgn.
  - hemiteloides Brgn.
  - leptophylla Bunb.
  - oreopteridia Schlth.
  - pinnatifidia Gutb.
  - polymorpha Brgn.
- Schizopteris dichotoma Gumb.
  - trichomanoides Goep.
- Sphenopteris moureti Zeill.

- Annularia sphenophylloides Zenk.
  - spicata Gutb.
- Asterophyllites dumasi Zeill.
- Sphenophyllum thoni Mahr.

- Poacordaites sp.
- Cordaites sp.
- Dorycordaites ottonis Gein.
- Artisia? (internal cast of Cordaites).

- Walchia filciformis Schlth.
  - flaccida Goep.
  - hypnoides Brgn.
  - piniformis Schlth.

- Cardiocarpus sp.
- Gomphostrobus bifidus Gein.
- Rhabdocarpus ?
- Samaropsis moravica Helmh.
- Trigonocarpus sp.

Zeiller says of the flora that true Permian is marked by the presence of—

Various species of Callipteris, not one in the Stephanian.
Schizopteris.
Pecopteris pinnatifidia Gutb.
Taeniopteris multinervis Weiss.
Walchia filiciformis Schlth.

The reported fauna includes:

Spines of Acanthodes.
Impression of a fish at Larche.
Worm trails?
Estheria.

Beds 4 to 7 are sands or argillaceous sands reddish, greenish or variegated and very micaceous and unconsolidated. The red color is due to iron and the various shades of violet and green are due to a reduction of the iron oxide; it is especially apparent along joints and cracks. The grain is finer and the bedding more definite than in 1, and there is more clay than in beds 2 and 3. The age of these beds is equivalent to the upper Rothliegende of Germany. Mouret suggests the possibility that the uppermost, No. 7, is equivalent to the Zechstein. In the red sandstone there are impressions resembling those of twigs and of rain drops, but apparently not of such origin, worm holes, and other irregular markings.

Mouret (1891) gives the following comparison of the beds north and south of the Central Plateau; he recognizes four well-sustained beds.

4. Superior and widely transgressive, Red sandstones and clays with occasional beds of the Autunian phase (shales of Millery, red sandstones of Allier, Autun, Blanzy, Brives, Rodez, Camares, etc.).

3. Median and transgressive on the lower. Shales, sandstones, limestones and bituminous shales, with impressions of plants and abundant remains of *Walchia* in the south (sandstones of Bourbon, Arkose of Cosne, ? shales of Muse, reddish sandstones of Blanzy, bed with fish and *Walchia* of Corrèze, of Rouergue and the Montagne Noire).

2. Transgressive on lower, A stage of more recent sandstone. (a). Commentry, Grand Moloy, upper beds of Montceau, series of Bois-d'Avaize, beds of Bourran at Decaizeville, sandstone of Najac and the Guépie, upper coaly sandstone of Realmont, coaly sandstone of the basin of Rodez and Requistra, upper sandstone of Camplong, perhaps also that of Neffiez, coaly sandstone of Brives. (b). Beds with an Autunian or Permian facies, especially all in the upper portion. (Shales of Igornay, Buxiere, Montceau, lower shales of Bert and lower red sandstone of Brives.)

1. At base the older carbonaceous sandstone (Epinac, Saint-Etienne, Rive-de-Gier, the Cevennes, Champagnac, and Auzits at Decaizeville, Carmac, Graissessac, Neffiez, etc.).

This is the same sequence as in the valley of the Saar—

4 = Upper Rothliegende.
3 = Middle Rothliegende.
2 = Lower Rothliegende.
1 = Upper Carboniferous.

Mouret's conclusions are as follows:

1. The oldest beds are Carboniferous.
2. The more recent Carboniferous sands are transgressive. Those of the south are equivalent to those of the north and perhaps are equivalent to the lower shales of Autun.

3. The beds with *Walchia* in the south are equivalent to the shales of Autun, perhaps representing the middle portion.
4. The red sandstones of the south are equivalent to the red sandstone of the north and perhaps the lower part of the shales of Autun.
5. There were movements of the earth during the Carboniferous and Permian, or of the waters, which caused successively greater transgression in each epoch.
6. After the deposition of the Permian sandstones there were movements which formed folds, more or less marked in the northeast and east and which became faults or depressions in the west and southwest.
7. The most recent Permian sandstones appear to be those of the Ramiere (Corrèze) and of Villecomtal (Ayveron) and are perhaps contemporaneous with the Zechstein.
8. Eruptive action was insignificant, far less than in the Vosges and in Germany.

DeLaunay in his *Géologie de France* speaks of a chain of lakes, lying in an old syncline, which extended from Vignan on the east to Brives (Vignan, Brousse, Requista, Najac, Decaizeville, St. Perdoux, Brives). A similar syncline to the south is marked by Graissessac. These basins were filled to overflowing with Permian sediment which possibly spread far and wide over the Plateau and united in a uniform cover over large areas and they show in a general way the same succession of beds from bituminous shales to fine red sandstones The only remains found in these beds are of fish and reptiles and impressions of leaves. DeLaunay sees in the color of the beds and in the fauna and flora evidence of an increasingly arid climate which found its culmination in the Triassic.

The peculiar arrangement of the series of coal basins which extend along the Grand Sillon Houiller through the central part of the Plateau is difficult to explain or to correlate with the general arrangement of the various basins in the old synclinals. It is apparent that the basins were at one time much larger and that they have been reduced in size and altered in shape by the great fault along which they are arranged. It is apparently more correct to arrange them as parts of older basins in synclines than as having anything to do with the structural lines indicated by the Grand Sillon and the valleys of the Cher, the Allier and the Loire.

Delafond (1919–20 and 1902) has given us his ideas of the probable fracturing of the Hercynian ranges as they were bent sharply to the south around the buckler of the western half of the Plateau, the Limousin. He conceives a set of radial fractures converging to the north and diverging toward the south in a fan-like manner. These fractures are traceable in the valleys of the Loire, the Allier, and the Cher, and in the Grand Sillon. The latter is very plain from Decize on the north through Souvigny, St. Eloy, Pontaumur, Champagnac, St. Mamet, Decaizeville, Najac, and Carmaux. On the east the valley of the Allier carries the basins of Brassac and Langeac in its upper portions; on the west the valley of the Cher is marked by the basins of Hérrison and Commentry. It is easy to see in these detached basins portions of large lakes in the old synclines, or separate small lakes in the same synclines. Delafond gives a figure, reproduced in figure 10, in which the basin of Creusot is continued in an irregular manner to the west until it includes the basins of Souvigny, Villefranche and Commentry, and so into the valley of the Cher. This explanation seems to be in full consonance with the structure of the rest of the Plateau.

De Launay (1921) says, however, that the Grand Sillon is a pre-Stephanian fracture with the coal basins arranged along its length, the present shape and location of the basins being due to renewed movements in Miocene time and to subsequent erosion.

In the extreme south of France lie the Permian exposures of the Montes de Maures and Esterel; these with the deposits of the Maritime Alps and of the greater part of Italy belong in the category of bordering deposits on the southern side of the Hercynian uplift, shading into the marine deposits of the Permian mediterranean.

In the French portion of these deposits a heavy conglomerate, interrupted by sheets of rhyolite and intercalated beds of clay carrying impressions of *Walchia piniformis* and *Callipteris conferta*, lies upon a mass of volcanic eruptives, melaphyr and pitchstone. Above the conglomerate is a series of red shales and marls with some sandstones and conglomerates. The whole exposure of these beds, from Toulon to Cannes, indicates a typical lagoon and terrestrial origin. The beds resemble, in a most striking manner, the Permian beds of the southwestern portion of the United States. There is the same rapid alternation and the same striking purple color. The red shales and sandstones are speckled and blotched with green, and the green color follows down the cracks and appears on the bedding planes. In several places there is typical weathering into "bad land" forms. No gypsum appears in these beds (so far as the author could see in his short examination of them), but in most respects it closely resembles the Double Mountain formation of Texas, and in the United States would be set down at once as hopelessly unfossiliferous.

Bertrand (1897–8, page 42) gives a description of the region north of Nice. The Permian is here well developed and in many places forms the base of the sedimentary series. Two divisions are clearly shown:

> 2. Red argillaceous shales. Sometimes very compact and sometimes shaly. The color is amaranth red with irregular patches of green which may be parallel to the bedding and lense-like in form, or may be very irregular—in spots and patches. The deposits are uneven, being very thick in some places and thinner in others. The bedding is well marked and toward the base the beds are more compact and arenaceous.
>
> 1. Largely sandstone and arkose, red or violet in color. Enclosing abundant detrital grains of quartz and feldspar and frequently rounded grains of gneiss and granite. The cement is argillaceous and often micaceous. At certain places there are intercalations of quartzite. Frequently these beds pass by the gradual diminution in the size of the grains into the argillaceous beds above. The beds are compact and the bedding planes are hardly visible.

The material of the beds is detritus from the Massif of Mercantour, which was apparently of some height and never covered by the sea during the Permian. A little north of St. Saveur the Triassic rests upon the crystalline schists, and as the Permian shows no evidence of erosion at the contact it appears that the Triassic was simply transgressive upon the Permian. It is probable that the sea extended but little north of this point. In some places the upper beds of the Permian were regressive and the Triassic lies on the lower beds, but in general there is no unconformity and the Triassic is transgressive. It is probable that there was an emerged land to the north of the Permian deposits which was continuous with the land to the north of l'Esterel and extended toward the east, so that the deposits on the north side of the Massif of Mercantour in the valley of the Stura di Demonte in Italy were distinct from those on the south and southeastern sides. In the valley of the Stura in Italy, and in the valley of Tinée in France, heavy conglomerates, breccias and phyllites give evidence of this high land.

A microscopic examination of the sediments shows a very general similarity with minor variations; there is much weathered feldspar and mica and the argillaceous cement is derived from decomposed mica. The red shales are simply advanced stages of decomposition of the same material. In some places, as at Cabanne de Nauthes, veins of copper have been found in the sandstone and shale. Potier reported traces of plants in the beds near St. Martin-de-Vésubie but Bertrand was unable to confirm this observation. The identification of the beds as Permian rests upon the evidence of their great similarity to the beds in l'Esterel, their transgressive character, and their relation to the overlying Triassic. The same beds extend to the eastern end of the Massif of Mercantour where they have been identified as of Permian age in Italy by Franchi.

Bertrand (page 119) suggests that there was a pre-Permian movement of uplift and that after this the transgressive filling of the basins by Permian began, the material coming from the degradation of the Massif of Mercantour and the associated portions of the northwest-south chain. The Permian deposits covered the slopes of the Massif only as far as St. Martin-de-Vésubie on the west and the Cime de l'Abisse (Italy) on the east. It is also suggested by Betrand that the coarse material of the upper beds may mean minor uplift at that time but this is on the supposition that the coarse material exposed is not merely a littoral phase of the upper beds.

The Permian of the Western Alps is so profoundly metamorphosed that it is difficult to determine the original nature of the beds exactly, or to determine even the age of some of the beds. DeLaunay in his *Géologie de la France* gives a map showing the four zones of the so-called Permian and demonstrating the deposition of the material in long troughs, probably oriented with the Variscan chain. The outer series runs through the

Massifs of Pelvoux, Belledonne, and Aiguilles Rouges to Mont Blanc. The general appearance is similar to that of the Verrucano. On the Alpine versant of the Cottien and Pennine Alps the determination is very doubtful, but there seems to be a great probability that the Permian was originally detrital and deposited in synclines performed in the Carboniferous and partly filled with Carboniferous before the Permian debris was laid down.

The Permian of the Pyrenees seems to have been deposited, in most places, under conditions very similar to those which prevailed in the Central Plateau of France. The lowest Permian present, the Saxonian, is a series of terrestrial shales and green argillites at Ariège. The mid-Permian is a series of red conglomerates, sandstones and argillites resting directly upon the Carboniferous in places, but the terrestrial deposition was interrupted by short-lived invasions of the sea, as indicated by some marine deposits found in the Haut Garonne. De Launay (*Géologie de la France*) considers that the presence of conglomerate in the Saxonian indicates that movement was continued in the Pyrenees after it had ceased in the Central Plateau. He believes further that the movement of the Pyrenees was continued to the east and is recognizable in the Monts des Maures and l'Esterel.

M. Roussel (1903–4) says that the Permian of the Pyrenees occurs in detached areas in the valleys of the Nive, Gave, Saison and Irati in the Basque Province. According to him they are mostly the remnants of an enormous mass of polygene conglomerate, alternating with black shales and carrying important lentils of limestone with cephalopods which recall those of the Carboniferous and Devonian. According to his map and description, the Permian was originally a mass of material transgressive over the isolated basins of the Carboniferous.

Caralp (1915) reported the presence of an amygdaloidal augitic melaphyr near Nescus (Ariège) which lies in the upper part of the red sandstones and clays of the Saxonian. Above is a second igneous layer covered by the siliceous limestone referred to the Thuringian. These igneous rocks are similar to the tuffs of the Massif of Sègala and appear to represent the material from a Permian volcano. Caralp had the good fortune to find the record of marine deposits of Permian age in the Pyrenees. In 1903[1] he published a short note concerning the occurrence of the Permian between Mont Perdu and San Juan de la Abadessas. Here there is a continuous exposure from 5 to 6 km. in breadth. No fossils have been found and the determination is upon physical and stratigraphic grounds. Three stages are recognized.

3. (Uppermost) Detrital material, mostly conglomerate and breccias of diverse origin, including fragments of the green shale of the base of the Permian and the red shales of the middle Permian enclosed in a cement of ferruginous clay.

2. Marly sands and argillite of a reddish tinge, and impregnated with iron. Its characters indicate that it is Saxonian in age and equivalent to the Rothliegende of Germany and the southern and western borders of the Central Plateau.

1. Essentially shaly and strongly resembling the marine beds of St. Girons. In this horizon there are sometimes sands and marls corresponding to the marls and sands of the Averyron and Autnois.

In various places there are interbedded sheets of porphyry and volcanic tuff. The bulk of the material is derived from the granite chain which forms the boundary line between France and Spain. At Bibas the dominant material is an arkose. The Trias is transgressive and unconformable on the Permian.

In a far more detailed paper M. Caralp (1903[2]) gives an account of the occurrence at St. Girons and of the region to the east as far as Foix.

Just south of St. Girons there is an exposure of the middle and lower Permian. The upper portion carries a marine fauna which, though not in excellent preservation, permits the determination of many forms. The section is as follows:

III. The upper Permian is hidden by the Triassic in this locality but is revealed at others, mentioned later.
II. The middle Permian = Saxonian. Unconformable on Lower Permian.
  3. Red argillites, marly in places, but uniform in general appearance, recalling similar beds in the Hérault. Almost always calcareous. 20 to 30 meters.
  2. (2) Sandy, greenish layer, with black mica and marly cement. Scattered occurrences of red marl and red calcareous lentils.
     (1) Reddish marls and argillites.
  1. (3) Coarse conglomerate, the pebbles and angular fragments of quartzite and similar material in a ferruginous cement. 7 to 8 meters.
     (2) White sandstone with a calcareous cement.
     (1) Red, marly, micaceous sandstone with red marlstone.
I. Lower Permian = Artinskian. Conformable on the Carboniferous.
  3. Greenish shales and argillites with reddish blotches; small, almond-like inclusions of discolored calcareous matter. Dominantly shales and argillites, calcareous only near the top. This is the zone of the marine fossils.
  2, Brown or gray sandstone with a calcareous cement.
  1. Fossiliferous shales and argillites; bright green on fracture, especially if wet, weathering to a brown or rusty color. Near the top narrrow and irregular lenses of gray calcareous material clouded in places with dark red.

Similar conditions continue westward to Foix. Toward the east, especially at Rimont and La Bastide, there is a bed above the middle Permian which occupies the position of upper Permian; the middle Permian retains its continuity and character but shows great irregularities in composition and material; the lower Permian retains its character but becomes more siliceous by secondary changes.

South of Rimont the upper Permian is well exposed, in most other places it is masked by the transgressive Triassic. Here it is largely a polygene conglomerate, often chalcedonic, or limestone and dolomite At the mines of Andreux it is somewhat different in phase and there are some sheets of porphyry. Caralp considers that his upper Permian is the same as is exposed in the Vosges and considers it to be continental in facies. It is quite distinct from the beds both above and below.

The lower Permian can be traced by slight but certain exposures as far as the Haute Garonne on the east and the upper valleys of the Aude on the west.

The marine fauna found in the Pyrenees has been located at St. Girons, the most important locality, and at Feillet, Singouant and Bargnac. All of these localities are in the same region of the eastern Pyrenees and in the same horizon; other more remote localities have been found in the Haute Garonne and the upper valley of the Aude. It is possible that the latter is of a different horizon.

The early preliminary studies by Haug and the more detailed studies by Caralp, confirmed by Haug, indicate the presence of three groups of ammonites.

Group I. Forms related to those of the Sosio limestone of Sicily.
Group II. Forms related to the Artinskian fauna of the Urals.
Group III. Forms unique in their occurrence in the Pyrenees.

To Group I belong—

Daraelites, equal to or near to *D. meeki* Gemm.
Daraelites (sp. n.,) ancestral to *D. meeki* Gemm. (?)
Gastrioceras. The identification based on the ornamentation and the close approach to several species from Sicily as *G. zitteli* Gemm., *G. sosiensis* Gemm., *Agathiceras suessi* Gemm., *Adrianites haueri* Gemm.
Forms related very closely to *Thallosceras.*
Forms recalling *Popanoceras.*
Paraceltites munsteri.

To Group II belong—

Forms resembling in their ornamentation *Gastrioceras suessi* Karpinsky, otherwise very near to *G. roemeri* Gemm. from Sicily.
Forms recalling *Pronorites* (perhaps *P. ouralensis* Karp.).

To Group III belong—

Forms with ornamentation analogous to *Trachyceras.*
Several species of *Paraceltites* different from those of Sicily.
Several species of *Gastrioceras.*
Many straight cephalopods.
A goniatite resembling some Carboniferous forms.
Besides the Ammonites there have been found echinoderms, bryozoa, some trilobites, brachiopods, rare pteropods, and lamellibranchs.

In remarks made on the occasion of the reading of Caralp's paper, Haug insisted on the presence of a *Pronorites* in the fauna, a *Griffithides*, a large *Euomphalus*, and many *Leiopora.* This he considers as indicating with certainty the equivalence with the beds of Sicily. Gemmelario examined the material and confirmed the conclusions of Haug and Caralp.

Permian in the Region of the Vosges

The region of the Vosges was so similar in its development, during the late Paleozoic, to the region of the Black Forest that the two form a close connecting link between the Permian of France and Germany. The Lower Permian is absent in the northern Vosges and the middle Permian is transgressive on the lower beds and upon the Carboniferous. Only in the southern portion and on the Lorraine slope is the lower Permian well known; here the middle Permian is similar to that of the north central Vosges and the upper Permian is unknown.

A general section slightly modified from Geike, Haug and others shows the following sequence.

Upper Rothliegende (Saxonian):
  4. Köhlbückel beds. Red arkose, feldspathic (kaolin) sandstone, conglomerate, breccia and shale. 500 to 600 feet.
    Tuff and melaphyr.
    Middle Rothliegende.
  3. Meisenbückel beds. Variegated tuffs and marls.
  2. Heisenstein beds. Black shales, limestone and dolomite (clays of Faymont).
Lower Rothliegende (Cuseler).
  1. Trienbach beds. Arkose, conglomerate, and shale. Blocks of igneous and metamorphic rocks. Unconformable upon and filling cavities in the older material. Keyser says conformable on older at Wierthal.
Transition beds.
  Erlenbach beds in the region of Valle, transition from Stephanian to Autunian.

At Courmont, Lomont, and Belverne (Haute Saonne) borings have shown 650 to 900 feet of red sandstone, thin beds of dolomite, limestone, porphyry breccia and flows of rhyolite. This indicates a continuation of the beds to the west and a connection with the Permian of the Morvan under the younger beds of the valley of the Rhone.

In the region of Valle and Ronchamp (Benecke and Wervecke, 1890) the lower beds are coarsely stratified argillites, very brightly colored, adjacent to flows of rhyolite. Here are found an abundance of the silicified stems of trees in a flora which contains Autunian species mingled with Stephanian.

The middle Permian is represented by the white arkosic sandstones (paving stones) of Giromangy and the shining red sands of Ronchamp. This, according to De Launay (*Géologie de la France*, page 181), is a similar facies to that of the Central Plateau and indicates active sedimentation with periods of aridity and a renewal of the volcanic activity first seen in the Stephanian. A similar development of the Permian is found at St. Dié.

Lepsius, in his *Geologie von Deutschland*, etc., page 423 et seq., gives a summary of the deposits in the small detached areas in the Vosges. In the southern Vosges in the region around Giromangy, Champigny, and Salbert, the depression is filled with Upper Rothliegende; claystone, variegated marl, red sandstone and conglomerate, 360 meters thick, lie unconformably upon the Carboniferous. In the region of Val d'Ajol, south of Remoremont in the valley of the Moselle, the complex is made up of clay shale, claystone, porphyry tuff and flows; in places the beds contain many angular fragments of gneiss, as in the vicinity of Remoremont. The flora is listed on a following page. Above the plant-bearing layers are coarse-grained arkoses and conglomerates 60 to 120 meters thick, which are reckoned as equivalent to the Upper Rothliegende.

At St. Dié and in its vicinity as far north as Dinon the section is as follows (taken from Lepsius' quotation from Velain):

	Meters.
5. Clayey sandstone with pebbles of granite, porphyry, etc.	20
4. Clayey sandstone and variegated marl. In upper part thin discontinuous beds of dolomite. The dolomite and sandstone contain pebbles of igneous rock and chalcedony	50
3. Conglomerate	0.5 to 1
2. Red clayey sandstone with red clay marl	6
1. Porphyry and melaphyr flows with conglomerate and claystone (porphyry and melaphyr tuff), porphyry breccia and conglomerate.	

Where the flows and the beds belonging to the Lebach stage are lacking, the Rothliegende beds begin with a conglomerate which filled the old depressions.

Lepsius calls particular attention to the bed of sandstone with dolomite layers (No. 4). He notes that this occurs in the various depressions of the Vosges and in the upper part of the sections in the Odenwald and Schwartzwald. He considers it the equivalent of the Zechstein.

The Trienbach beds = Cuseler = Lower Rothliegende of the Döhlen Basin, and have the following plants in common with the beds of the Döhlen Basin (*fide* Sterzel).

Callipteris conferta Strnb., type of.
Linopteris (Dictyopteris) schutzi (Roemer).
Odontopteris obtusa Weiss.
Sphenopteris oblongifolium Germ.
Taeniopteris (T. jejeunata close to T. plauensis).
Walchia piniformis Schlth.

There are also some forms present which are found in the Middle Rothliegende beds of the Döhlen Basin.

Callipteris gigas Gutb.
Odontopteris gleichenoides Stur.

The flora at Val d'Ajol contains an abundance of silicified specimens indicating an equivalence with the Middle Rothliegende of Saxony.

Psaronius putoni Moug.
    hogardi Moug.
    hexagonalis Moug.
Pinites fleuroti Moug.
Cordaites (Araucarites) valdajolensis Moug.
Cordaites (Araucarites) stigmolites Moug.
Calamodendron striatum Brgn.
    bistriatum Brgn.
Medulossa stellata Cotta.

In addition there have been found impressions of—

Cordiates sp.
Calamites gigas Brgn.
Callipteris conferta Brgn.
Sphenophyllum angustifolium Germ.

Lepsius regards this list as indicating Lebach age.

Sterzel lists as characteristic of the flora of the Vosges region—

- Linopteris (Dictyopteris) schutzi (Roemer).
- Medullosa (Myeloxylon).
- Odontopteris obtusa Weiss.
  - gleichenoides Stur.
- Pecopteris dentata Brgn. v. saxonica Sterzel.
  - (Calipteridium) gigas Gutb. v. minor Sterzel.
- Psaronius helmintholithus Cotta.
- Taeniopteris plauensis (T. jejeunata G. E.) Sterzel.
- Calamites striatus Cotta.
  - (cruciatus) foersteri Sterzel.
    - striatus Cotta.
- Sphenophyllum oblongifolium Germ.
- Poacordaites palmaeformis Goep.
- Cordaioxylon.
- Auricaryoxylon.
- Spongillopsis dyadica Gein.

Brittany

De Launay in his *Géologie de la France* has made very clear the position of the Armorican folds in Brittany. The Stephanian is known to lie in close relation to the old basins and is oriented with them; the Permian, if present, is transgressive upon the Stephanian and evidently is due to an over-filling of the older basins. At Littry in Calvados, the Stephanian is covered by a series of sands, sandstones, conglomerates and variegated marls with some dolomite. From its position and from the facies of the beds it is probably Permian but there is no conclusive fossil evidence.

Some imprints of fish, *Amblypterus* and *Paleoniscus*, and some plant remains have been found near Teille close to Ancenis. The plants have been identified as *Schizopteris gumbeli*, *Cordaites*, *Ottonis* and *Artesia*. The importance of these occurrences is in the support given to the proposition of the carrying over to southern Great Britain of the conditions of the lower and middle Permian of Europe.

A slight unconformity has been reported by Viellard between the sands and marls of the lower part and the calcareous beds of the upper part, which gives some support to the suggestion that the upper part corresponds to the Magnesian limestone of Great Britain.

Bordering Deposits of Southern Side of the Hercynian Chain

The complex of beds on the southern side of the Hercynian folds extends from eastern France through Italy, into Hungary and touches, perhaps, the northern portion of the Dalmatian coast.

This complex is primarily one of foreland deposits from the degrading Hercynian ranges but shades into delta deposits on the northern side of the old mediterranean Tethys. The terrestrial series is frequently interrupted by beds of limestone, especially in the later stages, due to short-lived invasions of the sea which spread over irregular and inconstant areas. Suess (vol. 111, page 110, English edition) speaks of the great fan of Carboniferous and Permian sediments which spread on the inside (southern side) of the folds from above Sion to the coast at Savona. This is the mass of sediments variously interpreted as to age, which is visible in the folded masses of the Alps from Mont Blanc, through eastern France and on the eastern side of the massif of Mercantour. The beds are largely altered sediments, semicrystalline and gneissic, with seams of anthracitic material and graphite resulting from plant remains. Suess says that the plant remains "bear witness to their (the beds) age," but it can hardly be said that there is any agreement of opinion as to the age of the beds. On the geological map of Italy (1889) the beds from Sion to Briancon are marked as Carboniferous and from Mount Chambeyron to Savona as Permian.

East of this the bordering deposits are very largely hidden, if ever present, under the Cenozoic deposits of the central plain of Italy. That such deposits do exist under the central plain is indicated by their appearance between Lago di Como and Lago di Gardo, in the Carnic and Julian Alps, and in scattered patches in the peninsula, as at Monte Pisano near Pisa, between Sienna and Grosseto, in the Island of Elba, near Orbetello, and in the valley of the Pescara River near Tregiara in the province of Abruzzi.

In these exposures the Permian or Permo-carboniferous-Triassic is terrestrial in character, commonly the "Verrucano," but there are intercalated limestones and, in places, volcanic deposits.

A table slightly modified from Frech will show the general assemblage of the beds of the late Paleozoic in this bordering region, which are referred to frequently as the Grödner Stage.

Southern Tyrol, Bordering Central Alps, Brenner and Western Alps.	Carnic Alps and the Karawanks.	Southeastern part of exposures.
Bellerophon limestone, in southern Tyrol only.	Bellerophon limestone = upper and middle Zechstein.	Rauchwacke, gypsum and dolomite.
Grödner beds Kupferschiefer. Upper Rothliegende. Middle Rothliegende.	Grödner beds Kupferschiefer. Upper Rothliegende.	White sandstone or thick dolomite.
Transgression and discordance.		
Upper Carboniferous, non-marine. Central and western alps only.	Lower marine Dyas, Trogofel limestone. Marine Upper Carboniferous.	

The Grödner beds are present in two divisions which include the "Verrucano."

2. Grödner sandstone, with irregular deposits of marl, red variegated clay and semi-stratified dolomite. Exceptional appearances of blue argillaceous limestone, and gypsum occur in connection with the "Verrucano."

1. Grödner conglomerate (Verrucano). Representing the quartz-porphyry of Bözen and sometimes enclosing pebbles of it.

It is seen that the Grödner beds are the deposits of a terrestrial phase, between the marine conditions of the late Carboniferous in the east and a continuation of the terrestrial Carboniferous in the west and the marine deposits of the invading Tethys which deposited the Bellerophon limestone of late Permian.

The Grödner beds are exposed in the Glarus Alps in Switzerland and in a line from the upper valley of the Dora-Baltea to Lago di Lugano and from Lago di Como to Lago di Garda. A middle Rothliegende flora has been found in the valley of the Trompia just north of Brescia, including *W. piniformis*, *W. filiciformis*, *Sphenophyllum fasciculata* v. *zwickauensis*, *S. ovata*, *S. suessi*.

At Monte Pisano, near Pisa, is the typical exposure of the "Verrucano," the succession given by Frech is—

3. Hard, shiny shale; lenses (?) of red sandstone. In Monte Vignal, in Sasso-Campo-naro, etc., there occur *Walchia piniformis*, *W. flaccida*, *Baiera*, *Ginkgo primigenia*, *Taeniopteris multinervis*, *Callipteris conferta*.
2. Sandstone conglomerate, and violet clay shale at Gemigna, Valentona, and on the crest of Monte Vignale, with *Callipteris conferta*, *Sphenophyllum* (*Trizygia*) *archangelina*.
1. Shale, at Collita, Triana, Villa Massaglia with *Sphenopteris lebachensis*, *S. bockingiana*, *Pecopteris dentata*, *P. hemiteloides*, *P. oreopteridia*, *P. densifolia*.

Similar beds and flora occur to the south as far as Orbetello. In the valley of the Pescara River, near Tregiara, a bituminous shale lying between the "Verrucano" and the Grödner sandstone carries *Walchia piniformis*, *W. filiciformis*, *Ulmania frumentaria*, *U. cf. selaginoides*, *Baeria digitata*.

The flora of the Province of Abruzzi is somewhat later in appearance than the others which, allowing for the possible difference due to geographical distribution, is similar to that of the Cuseler and Lebach of more northern and western areas.

Near Bözen are the great porphyry flows which lie upon the older beds and can be traced eastwardly to a point between Camelico and the Sexten Valley on the south slopes of the Carnic Alps, and in the valley of the Gail on the north slopes, between Maria Luggau and Kotschach (Frech, 1892–4, pages 336–341), where they are represented by the Grödner conglomerate, "Verrucano." Kayser (*Lehrbuch der Geologie*, vol. III, page 348) says that a similar or the same flora can be traced east to Lugano and Arona at the foot of Lago di Maggiore.

Farther east, between Neumarktl and Mazzon, on the south slope of the Karawanks in Ukrainia, the Grödner beds have yielded upper Rothliegende plants—*Voltzia hungarica*, *Baeria digitata*, *Ulmania bronni*, *U.* (?) *geinitzi*, *Equisitales* and fish scales. Still farther northeast, at Fünfkirchen, south of the Balaton Sea in Hungary, a similar flora has been found—*Voltzia hungarica*, *Boeckina*, *Baeria digitata*, *Ulmania geinitzi*, *Schizopteris permiensis*.

From south central Hungary, Reschitza (Resicabanya), in the district of Krasso-Szoreny, and from Banat (Banlak) a little to the west, Gothan lists the following plants, which he says evidently include both Rothliegende and Stephanian elements.

Alethopteris serli Brgn (?)
Callipteris conferta Sternb.
    naumanni Gutb.
Callipteridium gigas Gutb.
"Hymenophyllites erosa Morr." Probably a Callipteris.
Linopteris sp.
Neuropteris cordata Brgn.
Odontopteris reichiana Gutb.
Pecopteris arborescens Brgn.
    candolleana Brgn.
    pinnatifidia Gutb.
Pecopteris pluckneti Schlth.
    unita Brgn.
Sphenophyllum angustifolium Germ.
    oblongifolium Germ.
Taeniopteris coriacea Gopp.
Annularia carinata Gutb.
    sphenophylloides Zenker.
    stellata Schlth.
Lepidophyllum majus Brgn.
Stigmaria ficoides Brgn.
Cordaites principalis Germ.
Walchia piniformis Schlth.

The extension of the paleozoic mediterranean Tethys, through this same region of terrestrial deposits, is evidenced by the presence of marine limestones carrying the same, or a similar, fauna as occurs in the Pyrenees and Sicily. At Neumarktl there are Artinskian forms, *Thalassoceras* and *Popanoceras* (Haug, *Traité de Géologie*, page 801). Haug considers the breccia at Neumarktl equivalent to the "Verrucano," but Teller and Geyer (1899) consider it a phase of the Trogofels limestone, a higher horizon.

ASIA MINOR

Terrestrial deposits of Permian age are practically unknown in Asia Minor. The bulk of the upper limestone is Carboniferous and marine Permian, but at Heraklia (Eregli) and Amasso in the Bithynean peninsula the coal-bearing beds, with plants of Waldenberg and Saarbrucken age, are overlain by red sandstone, clay-shale and conglomerates which are considered to be of Rothliegende age (Phillipson, 1918). At Mersevan and Amasia plants have been recovered which are referred to Rothliegende forms, with some question. At present it is impossible to connect this isolated occurrence with any of the better-known regions.

PERMIAN IN SPAIN AND PORTUGAL

Outside of the deposits in the Pyrenees, there is no marine Permian recorded from Spain or Portugal. In Spain widespread deposits of red sandstone, with some grits and conglomerates, resemble the adjacent Permian and Carboniferous beds of France. At Busaco in Portugal, there has been recovered a flora which is considered to be of Autunian age by Haug (*Traité de Géologie*, page 902, following Lima, 1892 and 1895). Barrois records similar floras from small basins near that of Busaco which were referred to the mid-Carboniferous and the upper Carboniferous by Zeiller and Grand 'Eury. The whole Iberian Peninsula was land during the Permian and the Triassic (Huene, 1925). Fleury (1924) considers that the elevation began with the Hercynian movement and was a part of it.

Fauna of the French Basins.

	Moissy	Littry	St. Sever	Brive	Herault	Decaizeville.	Lodeve.	La Machine.	Allier.	Lorme.	Commentry.	Buxierre.	Blanzy-Creuxot.	Telots.	Igornay.	Autun.
Pisces:																
Acanthodes bronni Ag.						×						×			×	×
rouvillei Sauv.							×									
Amblypterus angustus Ag.		×				×				×						×
bayleyi Sauv.														×		×
beaumonti Edg.																×
bertheri Sauv.																×
bibractensis Sauv.[1]																×
(Paleoniscus) blainvillei Ag.															×	×
deplessi Sauv.									×			×				×
duvernoyi Ag.							×	×		×				×	×	×
gaudryi Sauv.															×	×
inaequilobum Blv.														×		×
levyi Sauv.																×
reussi Heckel.														×		×
rochei Sauv.						×									×	×
(Paleoniscus) voltzi Ag.										×				×	×	×
Cheiracanthus sp. Sauv.																×
Conchopoma sp.												×				
Elonicthys sp.												×			×	
Megapleuron (? Sagadous) rochei Gaud.																×
Paleoniscus (Amblypterus) arcuatus Egd.						×										
bonnardi Ag.																×
(Amblypterus) decorus Edg.									×		×					
landroti Sauv.[2]																×
longissmus Ag.																×
Pleuracanthus bonnardi Ag.															×	×
laevissimus Ag.															×	×
sessilis Jordan.											×					
Radianicthys? lallyi Sauv.																×
Amphibia:																
Actinodon brevis Gaud.																×
frossardi Gaud.															×	×
(?) latirostris Jordan.																×
major Gaud.																×
Aistopod?								×								
Protriton (Branchiosaurus) petrolei Gaud															×	×
fayoli Thev.											×					
Reptilia:																
Aphelosaurus lutevensis Gerv.							×									
Callibrachion gaudryi B. and G.																×
Cotylosaur indet.			×													
Nesosaurus (Geosaurus) cynodus Gerv.	×															
Haptodus bayleyi Gaud[3]																×
Pelosaurus laticeps Cred.					×										×	×
Sauravus costei Thev.													×			×
cambreyi Gaud.														×		
Stereorhachis dominans Gaud.															×	
Footprints:																
?Permomegacheirum zeilleri Delage.					×											
Invertebrates:																
Cyrpiodes.																×
Cyprinoides.															×	×
Nectotelson rocheri Brocchi.															×	

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[1] Possibly young A. reussi. [2] Possibly young of A. angustus. [3] Possibly equivalent of Paleohatteria.

CHAPTER VI

SUMMARY DESCRIPTION OF THE PERMO-CARBONIFEROUS AND PERMIAN IN RUSSIA

Kayser, in his *Lehrbuch der Geologie*, quotes from Archangelsky (1922), giving a general idea of the deposits of the Russian Permian and Permo-carboniferous. The deposits of the Lower Permian (Permo-carboniferous of the Russian geologists) in the western part of Russia (Government of Vladimir and the Volga region) are entirely different from those of the eastern portion, slopes of the Urals, and unconnected with them. The western beds are dolomitic limestones, dolomites and gypsum which were deposited in a desiccating bay of a late Carboniferous or post-Carboniferous sea. The fauna of these beds, called the Schustivo-Derjatinsk beds by Sibirzew, is an impoverished one, including *Fusulina longissima* v. Moll, *Schwagerina princeps* Ehrb., *Productus cancriformis* Tchern., *Schizodus wheeleri* Swallow, *Allorisma elegans* King, and so forth.

The deposits of the lower Permian of the Ural region is divided into two stages; a lower, the Artinskian stage, and an upper, the Kungurian stage. The Artinskian beds are predominantly clastic, including conglomerates, sandstones, shaly clays and subordinate quantities of limestone. The fauna of the limestone is partly Carboniferous in appearance but is an open-sea facies *Pronorties praepermensis* Karp., *Parapronorites tenuis* King., *Medlicottia artiensis* Gruen., *Agathiceras uralicum* Karp., *Athyris pectinifera* Sowb., *Spirifer waageni* Tschern., *Productus cancriformis* Tschern., *Productus cora* d'Orbig., and so forth.

The Kungur stage has beds which are lithologically similar to those of the Schustivo-Derjatinsk but are faunistically closer to the Artinskian with the exception that the ammonites and the brachiopods are much reduced in number. Apparently this stage, like the beds of the western region, were formed in a desiccating body of water which finally was so much concentrated that salt was deposited.

The western beds are conformable upon the Carboniferous; the western portion of the Artinskian beds of the eastern region are conformable upon the beds below, but toward the Ural mountains they are sharply unconformable upon the slopes of the mountains from whose debris they were largely formed. The Artinskian beds were continuous with those of the mediterranean Tethys to the east but they are now cut off from the sediments of that region by an elevation and subsequent erosion in the trans-Volga region.

With the passage toward Upper Permian time the sea retreated from the eastern region and there was developed a land area upon which was deposited a series of terrestrial deposits, red clays, red sandstones, conglomerates and gypsum. In these terrestrial deposits are found the remains of reptiles, labyrinthodonts, plants, and brackish water invertebrates (*Paleoanodonta* and *Paleomutela*). This is the Ufa stage.

The next series of deposits is from a sea which apparently spread from the north or northeast over the whole region of the Russian Permian, depositing limestone, dolomites and gypsum (in the more off-shore, western, region) and marly clay conglomerate and gypsum (in the more littoral area near the Ural Mountains). This is the Kasan stage.

Finally came a gradual retreat of the sea and the development of a second terrestrial phase, red sandstones and conglomerates, which is in part Permian but in some places, as in the Governments of Kostrova and Wolgoda, is definitely Triassic in the upper portion. This is the Tatarian stage. The group of beds included under Küpfersandstein by the older geologists has been broken up and distributed over several stages, even as low as the Ufa. The following table makes more apparent the arrangement and distribution of the various stages.

	Western facies. Government Vladimir and Volga.	Eastern facies. Trans-Volga and Ural regions.
Triassic.	Tatarian stage.	
	Kasan stage. Pelecypod Brachiopod } beds.	
Upper Permian.		Ufa stage.
Lower Permian.	Schustivo-Derjatinsk beds.	Kungur stage. Artinsk stage { Zone of *Parapronorites*. Zone of *Pronorites*.
Upper Carboniferous.	*Schwagerina* horizon.	*Schwagerina* horizon.

Kayser, in his *Lehrbuch der Geologie* (vol. III, pages 383–384, 1923 edition), gives the following statement concerning the beds in Russia, which is interesting as showing a different and somewhat more conservative opinion.

PERMIAN:

Tatar stage. Limnic deposits, red, and occasionally gypsiferous and saliferous. Brackish-water invertebrates, Anomodonts and Triassic plants.

Russian Zechstein. (Present in the Governments Kasan, Wjalka, and Kostrona, not present in the Government of Perm.) Light-colored limestones with invertebrates of the German Zechstein.

Kupfersandstein. (Present in the Government of Perm.) Conglomerates and sandstone with Theriodonts, Stegocephalians and Upper Permian plants.

Lower Red Sandstone. Red sandstone, clay shale and marl. Brackish-water invertebrates and plants.

PRE-PERMIAN (PERMO-CARBONIFEROUS OF THE RUSSIAN GEOLOGISTS):

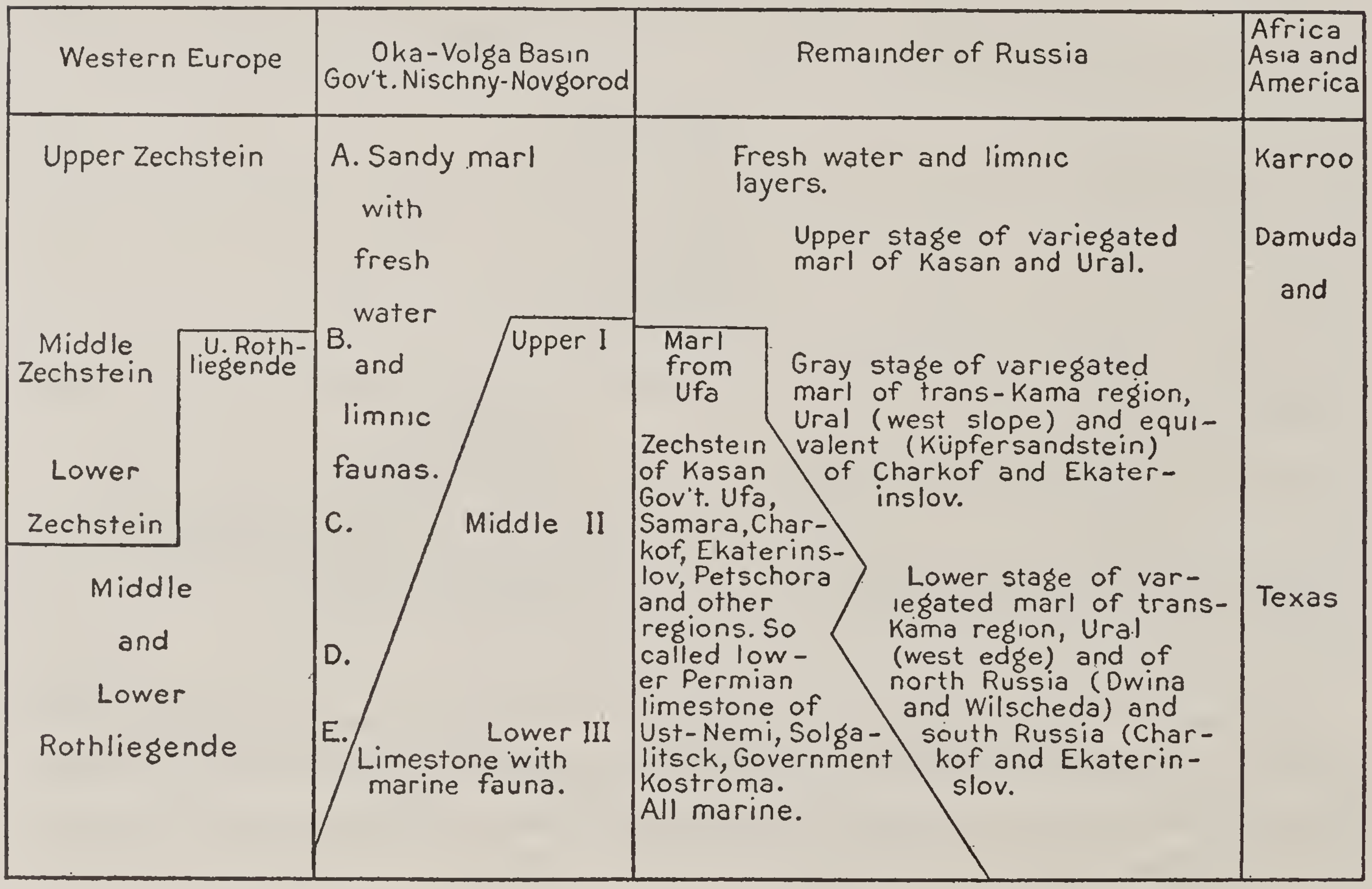
Kungur stage. Limestone and dolomites; brachiopods of the Artinsk stage and pelecypods of the German Zechstein; no cephalopods.

Artinsk stage. Marly sand, often conglomeratic, with occasional coal seams. Plants and cephalopods. Invertebrates, more than half, Carboniferous. Plants Permian.

In the Donetz Basin there is the following succession of beds.

3. Red and green marl with copper oxide, gypsum and salt.
2. Alternation of dolomitic limestone and variegated gypsiferous clay. Invertebrates of the German Zechstein.
1. Arkose, sandstone, clay shale and limestone. Upper Carboniferous invertebrates and at top Zechstein invertebrates.

Because of the interfingering of the terrestrial and marine beds the relation of the various divisions of the Russian Permian is not easy to visualize. Amalitzky (1892) has given the following outline which illustrates the peculiar relation:


Western Europe
Oka-Volga Basin Gov't. Nischny-Novgorod
Remainder of Russia
Africa Asia and America
Upper Zechstein
Middle Zechstein
U. Rothliegende
Lower Zechstein
Middle and Lower Rothliegende
A. Sandy marl with fresh water
B. and limnic faunas.
C.
D.
E.
Upper I
Middle II
Lower III Limestone with marine fauna.
Fresh water and limnic layers.
Upper stage of variegated marl of Kasan and Ural.
Marl from Ufa
Gray stage of variegated marl of trans-Kama region, Ural (west slope) and equivalent (Küpfersandstein) of Charkof and Ekaterinslov.
Zechstein of Kasan Gov't. Ufa, Samara, Charkof, Ekaterinslov, Petschora and other regions. So called lower Permian limestone of Ust-Nemi, Solgalitsck, Government Kostroma. All marine.
Lower stage of variegated marl of trans-Kama region, Ural (west edge) and of north Russia (Dwina and Wilscheda) and south Russia (Charkof and Ekaterinslov.
Karroo
Damuda and
Texas

The marly sand phase of the Oka-Volga Basin is a part of the upper variegated sandstone, the Tatarian stage; it is partly intercalated with and partly overlies the dominant Zechstein limestone and there is much intergrading, both horizontally and vertically. (In this connection see Netschaev, *Geology of Russia*, Comité Géologique, vol. 1, part V, fasc. 3, pp. 1–126, 1921.)

In the Timan region the Permian is but feebly developed but appears on both sides of the mountains as dolomites and gypsiferous layers. The lack of the upper beds, Tatarian stage, seems to indicate a rise of the land in this region with lack of deposition or subsequent erosion.

In the widely separated region of Permian deposits on the North Dwina and the Sukhona Rivers, Government Vologda, the succession of beds is as follows:

4. Marly sandstone (= Upper Zechstein).
3. *Glossopteris* stage, marls with lenticular masses of sandstone. A remarkably rich fauna of invertebrates, vertebrates, and a *Glossopteris* flora.
2. Marl and sandstone with a lower Permian flora.
1. Sandstone, marl and loose sand. A lower Permian marine fauna.

A summation of the general arrangement of the deposits of late Paleozoic in Russia would be about as follows:

Tatarian stage (= Thuringian, Triassic (*partim*).
    Red clay and grits, with argillaceous sandstone and intercalations of red marl and clay, spotted with green and blue. Some limestones with brackish water invertebrates as *Carbonicola* (= *Anthracosia*, *Najadites* and *Paleomutela*). This may be partly or wholly Triassic.
Permian (= Saxonian).–
    Brown marls and grits, limestone with pelecypods as *Allorisma*, etc.
    Gray slaty limestone with marls and friable grits (Zechstein).
    Grits and gray limestone bearing copper (Küpferschiefer).
    Red argillaceous grits with clay and with gray, brown and reddish marl. Plants, vertebrates and brackish-water invertebrates.
Permo-carboniferous.
Kungur Stage.
    Variegated argillaceous marls and limestones.
    Gypsiferous limestone, marls and dolomites. Gypsum and clay.
Artinskian (= Autunian = Lower Permian *auct.*).
    Conglomerate, sandstone, and shale with marly cavernous limestone and dolomite. Plants and invertebrates.
Uralian (= Upper Carboniferous).

The sheet of sediment spread out on the west slope of the Ural Mountains is apparently the most similar in structure, material and method of deposition to the deposits in the southwestern portion of the United States, of any in the Permian of the Old World. The sediments were deposited in a series of lagoons, flats and river channels, spread over a wide area. They are variously colored by the contained iron, the different tints being governed by the condition of the iron and this in turn by the relative humidity and the height of the water table. There is even evidence of considerable accumulation of wind-blown material. The vegetation grew in isolated favorable localities over the whole region. At intervals the area was invaded by marine waters which rarely retained their original character but either became brackish or desiccating pools overcharged with water-soluble salts. The pictures of the two regions, restored as best we may from the evidence of the sediments, are most strikingly alike.

From considerations of the size of the area and the character and source of the material, it might be expected that the terrestrial sediments of the west slope of the Urals could be traced to the region of the isolated basins of the nearest regions in Germany and Czechoslovakia, but such continuity was in part broken by the dominantly marine deposits of the Volga Basin. The terrestrial deposits can not be traced farther than Moscow and Kostrona. The thick deposit of younger material in western and southwestern Russia probably conceals some extension of the terrestrial conditions, perhaps even to the neighborhood of the Suedetes, for though the major part of the faunas of the two regions are radically different there are plant forms which are common to the two regions, or so closely related that there can be no doubt that some route of intercommunication was in use. It is more difficult to imagine the position of such a route of intercommunication

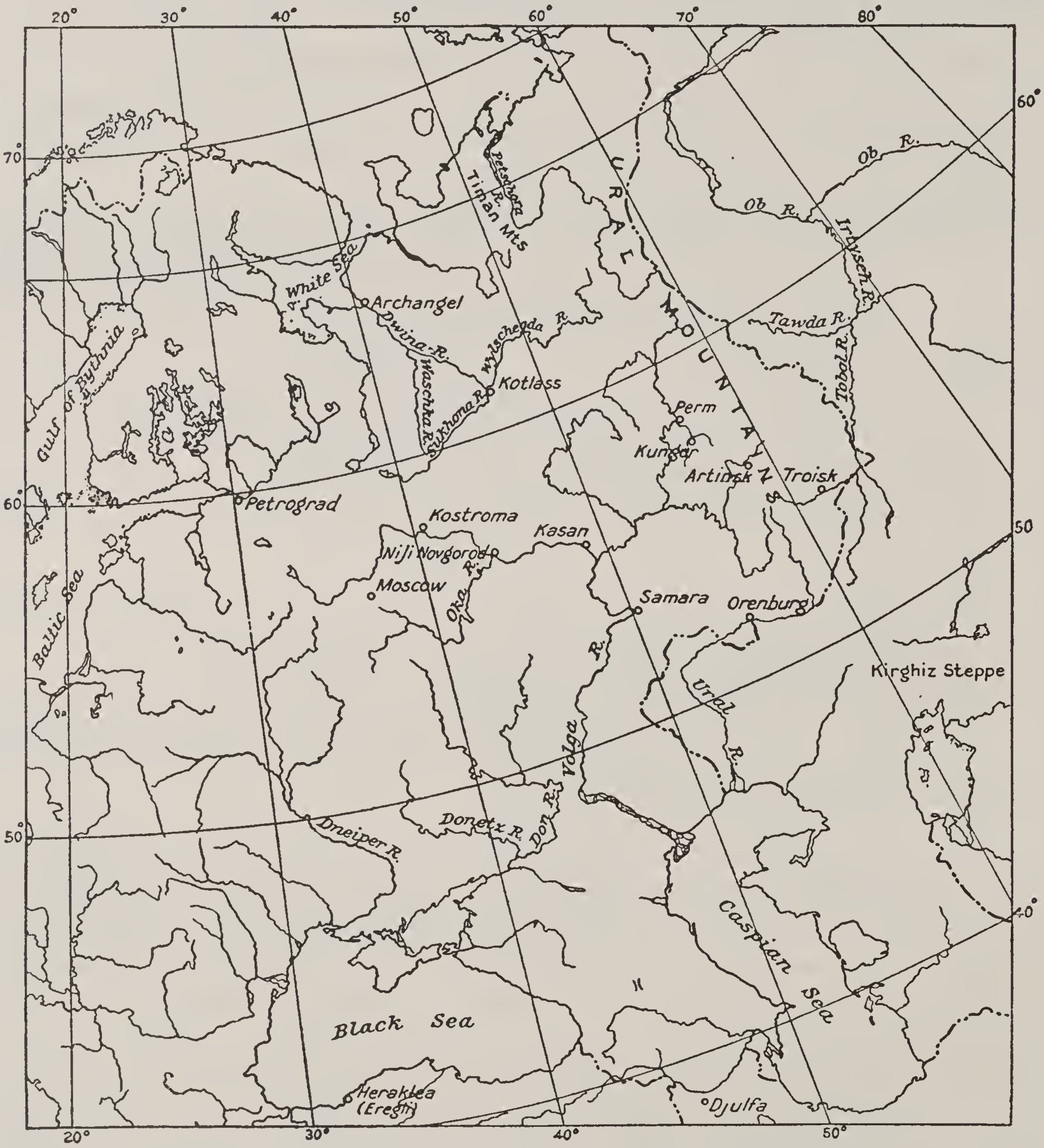


FIG. 12.—Sketch map of Russia showing localities mentioned.

between the Urals and the intermontane basins of the Hercynian chain than it is to imagine the route by which the fauna of the South African province found its way through India into Russia and even as far as Scotland. It must be remembered that the European fauna of Rothliegende time was already a highly specialized one with close adaptations to the environment, and some very small factor, difficult to detect, may have determined the possibility of migration or have prevented it entirely.

The terrestrial deposits of Permian near the village of Kotlas, near the junction of the North Dwina and the Sukhona Rivers, in the Government of Vologda, were described by Amalitzki (1900) as consisting of an upper bed of reddish-brown marl with a persistent layer of white limestone which shades in some places into a dolomite, and in others into a siliceous (quartzitic) rock. This upper bed is separated by a slight disconformity from a lower bed of stratified marl. At the point of contact there are large lentils of sand lying in depressions formed by previous erosion of the lower bed and covered unconformably by the upper bed. These lentils uniformly contain remains of plants and animals.

The lentil excavated by Amalitzki showed the following section:

Surface soil, 2 feet.
Bed of light grayish sub-soil (*podzol*) 2 feet.
Brown clay with pebbles, rarely with boulders of crystalline rocks, 6 feet.
Brown marl with thin layers of a lighter brown material, about 9 feet.
Limestone, dolomitic or quartzitic, about 9 feet.
Lentil of reddish-brown sand, feebly cemented by calcium carbonate, with flakes (*paillettes*) of gypsum, thin beds of calcareous or gypsiferous sandstone, abundant concretions, some containing impressions of ferns and bones of animals, about 36 feet,
Reddish-brown marl, about 12 feet,
Stratified reddish-brown marl with thin layers of white sandstone, about 60 feet

Amalitzki found that the concretions containing bones were located in the center of the lentil and that the concretions containing complete, or nearly complete, skeletons were in the lower part nearest to the center. Above and outside of these were concretions containing collections of mixed bones. The concretions are blackish or blue-gray. Amalitzki ascribed the color to the presence of the organic matter of the cadaver, acting upon the iron oxide present. He concluded that the remains had collected in a stream bed and that certain cadavers had been buried before decomposition could take place, other cadavers located near the bank had been decomposed, or torn to pieces before burial, and the concretions had formed around collections of disarticulated bones.

There are two points mentioned in Amalitzki's account which seem to make another interpretation possible. First, he states that all the beds of the lentil are inclined toward the center. Second, he speaks of the repeated occurrence of fronds of *Glossopteris*. The position of the beds points rather to the collection of the material in a pool or swamp, perhaps a drinking place, and the complete fronds of the fern could hardly have escaped wear and disruption in a stream with any current. It is easier to understand the condition of the bones and plants if we conceive of a swampy, or boggy, spot into which some animals penetrated by accident or fled, either in flight or pursuit. The disarticulated bones would be those of animals that died upon the shores of the hole and were dismembered by decomposition or by predatory animals. Amalitzki placed these beds in the upper Permian but Tschernyschew (*fide* Kayser) regarded them as belonging in the lower Permian.

Huene (1925) gives the following picture of Russia in Permo-carboniferous and Permian time.

> "North of the Hercynian folds lay the highlands of the Scandinavian area which reached to Scotland, Ireland and Wales. The region between the two elevated areas is now so deeply covered that the deposits of Permo-carboniferous and Permian time may not be observed but it is probable that they are of the same character as those of England. The eastern part of the area, all of Russia except the slopes of the Urals, was covered by the sea persisting from Carboniferous time, the Artinskian stage In Upper Permian time a new sea spread over Russia coming in from the northeast and advancing to the south and west until it was stopped by the highlands of central Germany and England. This, the Zechstein Sea, covered and filled many of the irregularities of the northern bordering slopes of the Hercynian uplift. The land fauna of the west slopes of the Urals originated before the advent of this sea and flourished on its border during its short-lived existence.
>
> As the Zechstein Sea passed away the northwestern part of Russia was converted into a semiarid steppeland where sporadic floods rushed through the stream channels, gathering and burying in sediment all that came in their course. This land was quickly occupied by plants (*Glossopteris* flora, in part) and land animals similar to those of the slopes of the Urals. It was this fauna which probably found its way still farther westward and left its remains at Elgin, in Scotland."

Suess (vol. III, page 361, English translation) says—

> "We may regard it as an established fact that for a long distance north of latitude 53° the Urals can not be separated from the foundation of the Siberian plain which is folded in the same direction as themselves."

This may have some bearing on the lack of remains of air-breathing vertebrate fossils on the east side of the Urals, as the land was, in all probability, much higher in Permian time, and there was a lack of the swamp and lagoon environment which seems to have been the favorite, or even necessary condition for the concentration of the animals of the time.

Our knowledge of the geology of the Siberian land is still most unsatisfactory. Saleski (1912) reported the finding of the Indian *Glossopteris* flora in association with the European Permian flora (*Callipteris*, *Dicranophyllum*, etc.), in the coal beds of Siberia, at Sudshenka near Tomsk in the Government of Tomsk, and in the valley of the Katanga (Kondoma) River in the Kutznetck Coal Basin and in Mongolia. He regards these occurrences as evidence of a land area in late Paleozoic time reaching from the Peninsular area of India to the North Dwina River in western Russia.

The beds show no evidence of glacial condition. This is, perhaps, one of the best bits of evidence of the possible route of migration of the land fauna from South Africa to Russia and Scotland.

Suess (1908) refers to the plant-bearing beds which lie upon the Paleozoic platform in Siberia as part of a great extension of similar beds which run through China and Japan. The age of the beds, which he calls the Angara Series, is certainly in part Jurassic, but just as certainly is part Permian (compare Saleski, cited above). The detached areas which extend to the south toward the Altai Mountains contain a flora regarded by Zeiller (1896[1]) as Permian. This is the Tungusian flora which in the Petschora region contains Carboniferous types, such as *Lepidodendron*. Suess (1908, page 36) provisionally agrees with Zeiller that the flora is of Permian age.

Some fish remains were described by Rohon (1889) from the upper Jenessei River and considered as Devonian in age; Smith-Woodward (1903) re-examined these and referred some of them to the Permian.

Tscherneyschew (1896) reported very briefly upon the geology of Nova Zembla. His observations were largely confined to the coastal regions but he states that in the interior of the island there are terraces of apparently Artinskian material.

The Permian of Spitzbergen is marine and there is apparently no Permian present on Bären Island.

The floral list for Russia follows:

URAL REGION:

- Callipteris broignarti Wen.
  - conferta var.
- Sphenopteris bifida Schmal.
  - erosa Morr.
  - lobata Morr.
- Calamities gigas Brgn.
  - decorans Eich.
- Cordaites sp.
- Cordaixoylon sp.
- Dadoxylon sp.
- Psygmophyllum (Noeggerathia) expansum Schimp. (Noeggerathia) cuneifolium Schimp.

Ullmania.
Baiera.

DWINA RIVER REGION:

- Callipteris.
- Gangmopteris cyclopteroides var. rossica Amalitzki.
  - major Feist.
- Glossopteris angustifolia Brgn.
  - communis var. rossica Amalitzki.
  - indica var. psygmophylloides Amalitzki.
  - stricta Bunb.

Noeggerathiopsis.
Psygmophyllum (Noeggerathia) expansum Schimp.
cuneifolium Schimp.

- Schizoneura.
- Sphenopteris.
- Ariodes crassipelta Kut.

Equisetum.

The Permian beds of Russia and Scotland must be considered in connection with those of South Africa, Madagascar and India so far as the tetrapod fauna is concerned. The only explanation for the migration of the Southern Hemisphere fauna into the Northern Hemisphere is by the progressive development of conditions which made it possible for the fauna to live and develop in new areas. The movement of the more active terrestrial forms, as the Dicynodonts, Therocephalians and Cynodonts, is easier to understand than the movement of the Pareiasaurians. As has been shown, the Pareiasaurians were inhabitants of the great aggradational area of the Karroo and were acclimated to the cooler and more humid conditions of the lower zone. Such or similar conditions may have been supplied by the preceding glaciation of India and Kashmir, and once beyond this the more northern latitude may have permitted similar conditions. It is to be noted that the Pareiasaurians were highly specialized by the time they left their remains in the deposits of Russia and Scotland and may have changed their adaptations to a considerable extent in the course of the migration.

It is the absence of any possibility of such an extension of the normal habitat through northern Africa and Central Europe which constitutes the most serious objection to Huene's suggestion that the route of migration was across northern Africa and the Iberian Peninsula into Russia and Scotland. Moreover the traces of the fauna discovered in India (*Dicynodon*), possibly Indo-China (?*Dicynodon*), and possibly Dicynodonts and Dinocephalians in the Triassic of North America, with the corroborative evidence of the movement of the *Gigantopteris* flora from eastern Asia into North America, must be taken for what they are worth as evidence of the route of migration so strongly indicated by the movement of the *Glossopteris* flora.

The great barrier to any intermigration between the two hemispheres was the mediterranean Tethys; the suggestion offered in the concluding portion of this work of the way in which the fauna might have crossed the barrier into Asia seems at least plausible.

The horizon of the beds on the slopes of the Urals is indicated by the presence of fishes of the Zechstein Sea. The red argillaceous grits with clay and marl beds immediately below the Zechstein suggest the Rothliegende, but, if so, they are very near to the upper limit for the flora contains *Ullmani* and *Baieria*. On the Petschora there is a mingling of the European flora with the *Glossopteris* flora (Gothan, 1911). As shown in the description, the beds of the Vologda region are very probably of the same age as those of the Urals; there seems no good reason for placing them higher.

It is very possible that the *Glossopteris* flora and the European flora were very widely distributed and that they descended from the uplands into areas where less humid conditions prevailed, just as the upland fauna descended. It is possible, of course, that the remains of the two floras are purely posthumous, that the remains were swept down from the uplands by stream action.

Fauna of the Russian Beds.

	Ural Mts.	Dwina River.
Pices:		
Acrolepis macroderma Eich	×	
murchisoni F. d. W	×	
rhombifer Eich	×	
Amblypterus (Paleoniscus) costatus Eich	×	
nanus Eich	×	
tuberculatus Eich	×	
Paleoniscus tscheffikinei F. d. W	×	
curtus Krotov	×	
kargalensis Krotov	×	
necschaievi Krotov	×	
Platysomus biarmicus Eich	×	
Pleuracanthus sp	×	
Trachelacanthus stschuriviskii F. d. W	×	
Amphibia:		
? Chalcosaurus rossicus H. v. M	×	
Discosaurs necshajevi Riabinin	×	
Dwinasaurus prima Amal		×
secunda Amal		×
tertia Amal		×
Platyoposaurus rickardi (Twelvetrees)	×	
stuckenbergi (Traut)	×	
Zygosaurus lucius Eich	×	
Reptilia:		
Anna petri Amal		×
Deuterosaurus biarmicus Eich	×	
Dicynodon rossicus Amal		×
trautscholdi Amal		×
wenjukowi Amal		×
Dwina prima Amal		×
? Edaphosaurus uralensis Riabinin	×	
Gordonia (Dicynodon?) annae Amal		×
Inostranzewia alexandrae Amal		×
Karpinskosaurus sp. Sush.[1]		×
Kotlassia prima Amal		×
secunda Amal		×
tertia Amal		×
Pareiasaurus elegans Amal		×
horridus Amal		×
karpinskii Amal		×
tuberculatus Amal		×
Rhopalodon fischeri Eich	×	
mantelli E. d. W	×	
murchisoni Pander	×	
wagenheimi E. d. W	×	
Venjukowia prima Amal		×
Uncertain forms:		
Brithopus (? Deuterosaurus or Rhopalodon)	×	
Dinosaurus (probably Rhopalodon)	×	
Orthopus (? Deuterosaurus or Rhopalodon)	×	
Syodon (? Deuterosaurus or Rhopalodon)	×	
Melosaurus (Indeterminate)	×	
Eurosaurus (? Deuterosaurus or Rhopalodon)	×	
Cliorhizodon (? Deuterosaurus or Rhopalodon)	×	
Invertebrates:		
Estheria		×
Anthracosia		×

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[1] Sushkin, 1925.

CHAPTER VII

SUMMARY DESCRIPTION OF THE PERMIAN BEDS OF GREAT BRITAIN

There is much uncertainty in the delimitation of the greater part of the Permian beds of Great Britain. Much that has been recorded as Permian and so mapped has later been placed in the Triassic or in the upper part of the Carboniferous. In general five areas of Permian are recognized in England and Scotland:

1. A southern area in Somersetshire and Devonshire.
2. The Midland area.
3. The northeastern area reaching from Durham to Nottingham and perhaps even farther south.
4. The western area in Lancashire, west Yorkshire, Westmoreland and Cumberland. These areas are continued in the small deposits found in Ireland and the Isle of Man.
5. The small and disputed areas in Scotland.

The areas discussed in this paper are the ones shown on the geological map of the British Isles, 2d Edition, 1912, except as noted in the text.

The Westphalian and Armorican foldings affected England in the same manner that they did the western part of the continent of Europe. Due to this movement the sea retreated eastward into Russia and the central and western part of the continent was raised to continental conditions.

The historical record furnished by the terrestrial deposits of this interval is most broken and faulty; it is the equivalent of the Uralian, the Stephanian and the Ottweiler, but no deposits in England can be exactly correlated with beds of these ages upon the continent. In most of the occurrences the Permian lies unconformably upon the Carboniferous. Jukes-Brown (1922) says that England was occupied by swamps during this time but that the greater part of the deposits were removed by later erosion in the interval now represented by the Permo-Carboniferous unconformity, and that the equivalent deposits are to be found at Littry in Normandy, and at Laval and Margenne in southern France.

In figures 28 and 29 of the 4th edition of his book, Jukes-Brown (1922) presents maps to demonstrate the continuity of the folds of Armorican and Westphalian age from France into Great Britain. Due to a diversion of the direction, the folds in Great Britain are not all continuous with the Armorican direction of France. The great Lancashire folding and faulting has a general northwest-southeast direction; it is equal in time to the Armorican folds but is parallel with the older Caledonian foldings. This flexure appears as a fault on the northwest side of the Lake District with a throw of 1,200 feet, but passes beneath the Permian deposits without disturbing them. The Lake District was apparently raised as a broad anticlinal swell and an immense amount was removed by erosion during Stephanian time. There are several subsidiary flexures, or developments of the major fold, as the Lancashire syncline from Lancaster to near Bentham and the Ingleton coal field, with an outlier of Permian; the Pendle anticline, extending from Pately Bridge to Garstang, with a Permian outlier near Clitheroe on the Ribble; the Todmorton anticline, extending through Todmorton, Heptenstall, and Keighley, to Harrowgate.

The second great flexure is the Pennine flexure running approximately north and south and in large measure dividing the Permian deposits of north and central England into eastern and western portions.

A third set of flexures, the Cornubian, runs through Somersetshire and Devonshire. This set is more or less clearly traceable across southern England and the folds are continuous in direction with the folds in Brittany; there is little doubt that the same structure is traceable in the Channel in the vicinity of the coast of Devonshire. The direction of the folds and the local conditions were much affected by a series of volcanic extrusions and some deep intrusions at about the time of their formation.

Jukes-Brown says of the English region that the cessation of the Armorican disturbance left Great Britain much altered in physical features.

> "The great depressions which had been occupied by the seas of the Carboniferous period were broken up and new ranges of hills had been raised across them, and thus a new set of physical features was formed. The Scottish hill ranges were, of course, already in existence, as were also the hilly districts of Wales and the east of Ireland; but the opening of the Permian period found a great range of mountains occupying not only the whole of southern England but running westward far out into the Atlantic Ocean and including all the southern part of Ireland.
>
> "Moreover, these western highlands seem to have been connected with those of the eastern region by hills of less elevation, but still of a sufficient height to separate a large depressed area or basin in the south from the plains and lowlands which lay to the north of it. This east and west barrier probably consisted mainly of a series of ridges and valleys which had a general north and south trend, but its southern border was formed by the northern line of Armorican flexure, a continuation of the Glamorgan, Bristol, and Mendip ridges.
>
> "Further a low range of undulating uplands connected those of southern Scotland with high ground over the eastern Midlands of England. Though then of no great height, this was afterward to be raised into the Pennine Chain.
>
> "Lastly the western border of the English Midlands had been ridged up into the Malvernian range, an uplift in which all the Old Red Sandstone country to the west probably participated, in so far that it was raised into a high-level plateau, far above the plains and depressions in which the Permian and Triassic deposits were accumulated."

As a result of these movements the deposits of the Permian in England are largely terrestrial but there was an invasion of the sea in late Permian time. There are two distinct areas—

I. The eastern, which is the marine phase of the late Permian and records in its deposits—the Magnesian Limestone, a phase of normal marine deposition, a phase of climatic variation, and a littoral phase.

II. The western, which is dominantly terrestrial in the appearance of the deposits. The beds are separable only with difficulty from the Triassic above and the Carboniferous below, resulting in much difference of opinion as to the dating of certain beds and of portions of others. These beds included numbers 1, 2, 4, and 5 of the Yorkshire sections given below.

These two areas of Permian deposition were separated by the Pennine Chain but in the later part of the period the degradation of the mountains permitted the marine waters to extend west and leave thin beds of Magnesian Limestone with the characteristic dwarfed fauna, on the western side, as in the region of Penrith (Jukes-Brown, page 205).

The eastern sea extended as far south as Nottingham, where the littoral phase is very pronounced. Lake and Rastall (1920) give the following sections to show the character of the beds in different regions and the progression toward the littoral phase of the south.

AT DURHAM:

4. Red marls and sandstone. Thin, and with difficulty distinguished from the Triassic.
3. Magnesian Limestone. The lower part compact and barren, the middle part cavernous and most highly fossiliferous, the upper part concretionary or oolitic with few fossils. 600 feet at Durham.
2. Marl slate. A calcareous shale with many fish impressions. Variable in thickness but not exceeding a few feet.
1. Yellow sands unconformable upon the Carboniferous.

IN YORKSHIRE:

6. Upper red marls.
5. Upper Brotherton limestone.
4. Middle marls and sandstones. With ripple-marks, suncracks, worm tracks and foot-prints.
3. Lower limestone.
2. Marl slate.
1. Yellow sands. Sometimes with a basement breccia which thickens toward the east.

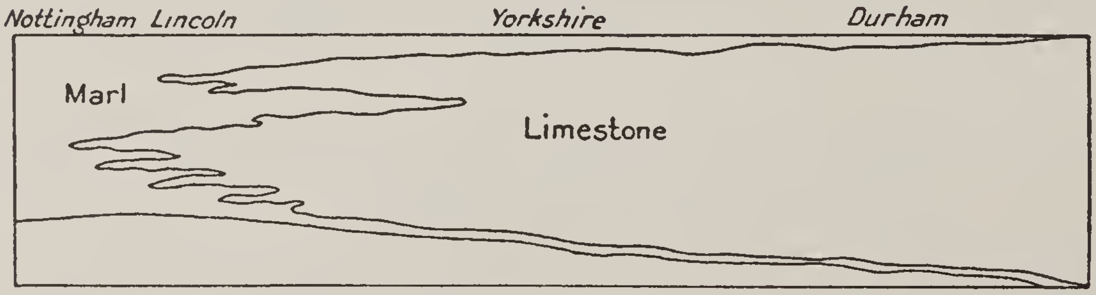

FIG. 13.—Section to show phases of deposition in the Zechstein Sea of eastern England. After Lake and Rastall.

The limestone decreases in thickness toward the south; numbers 5 and 3, together, equal only 450 feet and die out to the south. The marl slate increases in thickness, it is 3 feet at the mouth of the Tyne, 10 to 12 feet in Yorkshire, 50 to 100 in Nottinghamshire and 200 feet in Lincolnshire. The Middle marls (number 4) are absent in Durham, 30 to 50 feet in south Yorkshire, 140 feet in Lincolnshire. The upper red marls are absent in Durham, 50 feet in Yorkshire, 80 to 100 in Lincolnshire. Lake and Rastall give the accompanying diagram (Fig. 13) to illustrate the change in the phase of deposition from north to south.

These sections show, according to Jukes-Brown, first a deposition of sands, muds and calcareous marls from the streams descending from the Pennines; as the hills were worn down the waters became clearer and the deposits are largely of Magnesian Limestone. Toward the south the proximity of the shore determined the increased quantity of marls, sands and clays. From the character of the dolomitic limestone, its method of deposition and the dwarfed fauna it is assumed by some that the waters of this sea of Zechstein time were over-salt and stagnant, comparable to the Caspian Sea (Jukes-Brown), and by others that the deposits were formed in lakes, especially in the southwest and west, when the sea transgressed over the reduced Pennines.

Hickling (1909) has described footprints from beds of Permian age in Nottinghamshire, at Penrith, and in Devonshire. See also, Huene (1925).

The terrestrial deposits of the western side of the Pennines are typically terrestrial in their rapid variation in character and sequence from place to place.

Lake and Rastall (1920) give the following sections from Penrith in the Vale of Eden:

4. Red marls and shale which may be Triassic.
3. Magnesian Limestone. Not over 25 feet in thickness.
2. Hilton shale. Dark colored, many plants resembling those of the Küpferschiefer.
1. Red sandstone, breccia and conglomerate. Sometimes over 1,500 feet in thickness, at Penrith coarse and strongly current bedded. The whole bed becoming thicker from north to south.

Jukes-Brown makes the suggestion that the lower part of the Penrith sandstone may represent the lower part of the Magnesian Limestone as well as beds of a lower stage. This would make the lower part homotaxially equivalent to the Rothliegende of Germany as the Magnesian Limestone is undoubtedly Zechstein in age. The sandstone is largely quartz grains, worn and rounded like desert sand; the suggestion is made that they were accumulated upon a barren, arid surface and then swept by streams or wind into the aggrading area. The strong current bedding and the direction indicated by the nature of the deposition points to an eastern origin of the material rather than to the Lake District.

The same, or similar, sandstones are found lying on the Carboniferous on the west side of the Lake District, at Gosforth and south of Whitehaven. In all probability the small patches in the north of Ireland, near Cooktown in County Tyrone, and Armagh in County Armagh, are extensions of the area of deposition in the Eden Valley and are connected with it by the small deposits in the Isle of Man near Peele.

Haug (1907, page 830) cites the Permian age of the volcanoes of southeastern Scotland as additional evidence for connecting the red deposits with those of middle Rothliegende time of central Europe.

The Permian areas of the Midlands, Shropshire, Worcestershire and Warwickshire are almost exclusively, if not entirely, lower or middle Permian. The beds are cut off by unconformities above and below, but it is not possible to say whether the upper and lower portions are entirely Permian or whether they shade into the Triassic above and the Carboniferous below. Originally all the red and purple beds between the definitely determinable Carboniferous and Triassic were listed as Permian, but most of the lower and middle beds of this series are now placed in the Carboniferous. A general section suggested by Jukes-Brown for the Midland area includes—

3. The Enville marls. These are purple sandstones, marls and consolidated breccias made up of fragments of older paleozoic material from the marginal lands. Probably came from the south and were deposited in a small lake.

2. Trappoid breccia. The tillite of Ramsay's Permian glacial stage.

1. Conglomerate group. Material carried into lakes by streams and lying conformably on the Keele Sandstone; this may be Carboniferous, Stephanian.

In southeast Shropshire and southern Staffordshire in the Clent and Abberley Hills, there are—

2. Marls, with a trappoid breccia, especially at the base. The breccia pebbles are striated and constitute the evidence used by Ramsay for a Permian glacial stage in England. The striations are now regarded as due to slickensliding.

1. Calcareous sandstone, locally conglomeratic, interbedded with marl and sandstone. In this layer was found the Stegocephalian *Dasyceps*, near Kenilworth, and footprints occur in an equivalent horizon at Dumfries. The matrix at Kenilworth is a "coarse, soft, somewhat clayey sandstone, yellowish to dark red in color and with small included clay balls." (Huene.)

The Southern Area

The Permian of Devonshire and Somersetshire lies unconformably upon the older rocks. It is largely an irregular series of beds which were deposited on the uneven surface of the older land; much of the material is torrential or purely terrestrial breccia derived from the igneous elevations. The rocks of the different portions of the Permian, at least the lower beds, can not be regarded as contemporaneous in formation, certainly they are not continuous over large areas. The sedimentation seems to have been largely or entirely in lake basins. According to Jukes-Brown the beds are divisible into four types—

4. Red marl.

3. Exposed across the mouth of the Exe is a sandstone with breccia or red marl. This shows ripple-marks, sun cracks and footprints.

2. A stony marl, breccias and conglomerate composed almost entirely of debris from Devonian rocks; little or no igneous material has been found in this series. This series is succeeded north of Watcombe by breccias and sandstones with some very large included fragments, some up to 4 to 5 feet in diameter. This series extends to Teignmouth and along

the coast to Dawlish, north to Exeter and inland, to appear under Haldon Hill. It is probable that the Permian covered all of Devonshire between Dartmoor on the south and Exmoor on the north at the time of its deposition; some parts, as near Dartmoor and Exmoor, were apparently deposited as breccias upon the land surface. To the south outliers of the same series are found in Start Bay near Kingsbridge and Plymouth. Fragments of similar rock have been dredged on the southeast coast of Cornwall, off Dodman Point, and traces of the same rock have been dredged from a point 12 miles southeast of Lizard Point.

1. Watcombe clays; exposed at Torbay and Torquay. These are red and purple clays probably derived from the destruction of Devonian rocks and deposited in lake basins.

The arrangement of the deposits was probably governed by the folds of pre-Permian age which are continuous in direction with the Armorican folds of France, but the whole arrangement and the character of the material was much influenced by the igneous masses in the vicinity and by the local flows of lava which are intercalated in the beds.

The disputed deposits in Scotland which have been assigned to both the Permian and the Triassic lie in Dumfriesshire, Wigtownshire, and Kirkcudbrightshire, Ayrshire and the Isle of Arran, and Elginshire on the border of the Mowray Firth. The weight of opinion is shifting to regard these deposits as of Triassic age and they are so shown on the Geological Map of the British Isles, Edition of 1912, but Huene (1908 and 1913), Watson (1909) and Hickling (1909) have given evidence from the affinities of the fossil reptiles and of the footprints that they are in part of Permian age.

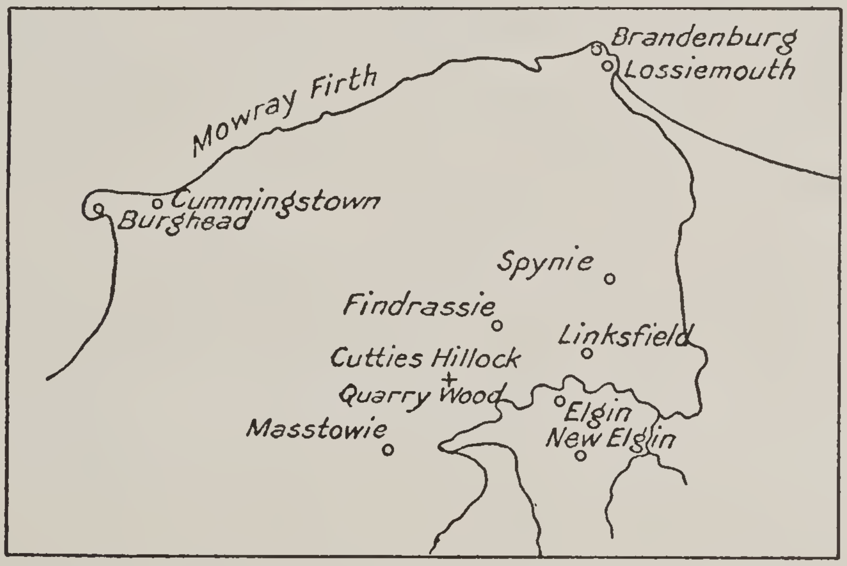

Fig. 14.—Sketch map of region around Elgin, Scotland. After Huene.

At Arran there are 1,000 feet of bright-red sandstone below the proven Triassic; these are strongly current bedded and more closely resembling the sandstone of Penrith than that of St. Bees.

In Ayrshire and in the Thornhill Basin of northern Dumfriesshire there is a bright-red sandstone interbedded with contemporaneous lava flows and ash beds. Jukes-Brown points out that such relations are common in the German Permian and rare in the Triassic of the same region.

At Dumfriesshire the lower sandstone carried footprints, described by Hickling (1909), and is overlain by a breccia and conglomerate which may be of Triassic age. Lake and Rastall (1920, Chapter 23) state that many rocks in Fifeshire may be of the same age.

The much-discussed beds of Elginshire, as exposed in the vicinity of Elgin, are undoubtedly of Triassic age in their upper portion and may be of Permian age in the lower part. A section of the beds is as follows:

- Triassic:
  - Lossiemouth.
  - Spynie.
  - Findrasie.
- Permian (?):
  - Cutties Hillock.

The Cutties Hillock beds are exposed from Cummingstown to Coversea as a coarse, yellowish, crossbedded sandstone of varying degrees of hardness, with occasional beds of pebbles completely or partially rounded. Sometimes the beds are flaggy with an abundance of footprints as at Cummingstown. East of Elgin, at Cutties Hillock, the sandstone is of the same character and has yielded *Elginia*, *Geikia*, and *Gordonia*. Many of the pebbles have the appearance of "Dreikanter" and the sand grains are rounded as by wind action. Both Watson (1909) and Huene (1908 and 1913) assume that the beds were deposited in a lake bed which was surrounded by a great arid waste of wind-blown sand. Watson suggests the possibility that the region around Cutties Hillock was an oasis in a desert region.

Jukes-Brown suggests (page 212) that toward the close of the Permian the basin in the northwestern part of England occupied a very large area, extending across all of Lancashire and much of Cumberland and Westmoreland; it sent arms across the Solway into the valleys of the Nith and the Annan. To the west it occupied all of the Irish Sea and covered the northwest portion of Ireland as far as the borders of Cavan, Monaghan and Tyrone, and extended north as a gulf which covered the Firth of Clyde and Ayrshire. In this great lake the regions of Wigtown and Kirkcudbright stood as an island. The southern shore lay in the southern Midlands, narrowing to a gulf in southern Lancashire; the shore probably passed west between North Wales and the Isle of Man.

The terrestrial Permian deposits of England can only be placed in the lower Permian with reservations, unless that term is meant to include all of the Rothliegende. The extension of the Zechstein Sea south and west was over a land similar in all respects to that which lay on the northern border of the Hercynian uplift in Germany and the effects of the transgression were the same in both places. The two regions can only be considered as parts of one whole. The presence of *Protorosaurus* in the upper beds of both places is a supporting bit of evidence for their equivalence. One is tempted to think of *Protorosaurus* as a shore-living, perhaps littoral, form closely associated with the borders of the Zechstein Sea.

The red sandstone at the base of the Triassic in Heligoland is in the stratigraphic position of the Permo-triassic of England and Germany and may be a visible bit of the connecting terrestrial deposits on the southern border of the Zechstein Sea.

The unknown highland, which lay between the terrestrial Permian of the Midlands and of Devonshire, was the home of the tetrapod fauna which has left such scanty remains in England and was a part of the migration route between North America and Europe.

Fauna of the basins in Great Britain.

	East England.	Midlands.	Elgin.	Dumfries.
Pisces:				
Acentrophorous (Paleoniscus) abbsii Kirkby	×			
altus (latus) Kirkby	×			
varians Kirkby	×			
glaphyrus Ag	×			
Acrolepis exscuptus Kurtz	×			
sedgwicki Ag	×			
Coelacanthus granulosus Ag	×			
Dorypterus hoffmanni Germar	×			
Globulodus macrurus Ag	×			
Janassa bituminosa Schlth	×			
Paleoniscus frieslebeni Blv	×			
longissimus Ag	×			
macropthalmus Ag	×			
Platysomus gibbosus Ag	×			
Pygopterus humboldti Ag	×			
Amphibia:				
Dacyceps bucklandi (Lloyd)		×		
Reptilia:				
Adelosaurus (Proterosaurus) huxleyi (H. & H.)	×			
Dasygnathus longidens Hux			×	
Elginia mirabilis Newton			×	
Geikia elginensis Newton			×	
Gordonia duffiana Newton			×	
huxleyana Newton			×	
juddiana Newton			×	
traquari Newton			×	
Oxyodon britanicus v. Huene		×		
Proterosaurus speneri v. Meyer	×			
Telerpeton elginensis Newton			×	
Footprints:				
Acibates sphaerodactylum (Pabst)		×		
Batrachichnus lyelli Hickling				×
Chelichnus ambiguus Hickling				×
megacheirus Hickling				×
Eumeckichnium longipollex Nopsca		×		
Harddakichnium dolichodactylum (Harddaker)		×		
Herpetichnius bucklandi Jardine		×		
Herpetichnium loxodactylum (Hardakker)				×
ungulatum Nopsca		×		
Korynichnium hardakkeri Nopsca		×		

CHAPTER VIII

SUMMARY DESCRIPTION OF THE PERMO-CARBONIFEROUS DEPOSITS IN CHINA AND MONGOLIA

Our knowledge of the geology of China is still so limited that any descriptions must be accepted as in a considerable degree provisional, but certain broad facts are sufficiently well established to permit of some understanding of conditions in the late Paleozoic. It is apparent that both marine and terrestrial beds of this age occur in China, though, as yet, no tetrapod fauna has been reported.

A summary by Lee (1921) gives the best general view of the distribution of the late Paleozoic deposits and may be used as a starting point. According to him the Permo-carboniferous (Anthracolitic) is well developed throughout China. In the northern provinces, Manchuria, Shantung, Chili, Shansi, Shensi, Honan and probably the east half of Shensu, the terrestrial phase is dominant, with coal beds, shales and sandstones. In the southern Provinces, to the south of the Tsingling Range, the phase is dominantly marine, but in neither region is the dominant phase exclusive of the other, for there are intercalated beds of marine limestone in the northern section, decreasingly important toward the north, and there are coal seams in the south. The two phases meet and mingle in the region of the Yangtse Valley and in the Tsingling and Nanshan Ranges.[1]

The Permo-carboniferous series is called the Shansian Series by Lee and is said to rest directly upon the Sinian in northern China; above, it merges into a coarse, unfossiliferous, yellowish or reddish sandstone of considerable thickness. In the province of Shansi the series is divisible into—

2. The Productive Measures. Variegated sandstone with subordinate sandy shales and seams of anthracite.
1. The Taiyang Series. Limestone alternating with ironstone-bearing shale and fireclay, with occasional coal seams. Capped by a fossiliferous limestone (*Fusulina*) with chert.

In western Shantung the Shansian is known as the Poshan Series, where it has intercalated lavas and tuffs in the upper portion. The fossils are regarded as equivalent to those of the Viseian of Europe, at least the fossils of the lower part are called equal to the Lower Carboniferous of Europe. Girty thinks that some of them, at least, are Pennsylvanian. Böse says (1917) that the fossils seem to belong to the Permo-carboniferous but that the evidence is too slight for definite commitment. At Loping (*fide* Böse) only *Gastrioceras* is indicative. In the lower part of the section, at Taipashan, near Tshatien, in the Province of Szechwan, *Agathiceras cf. suessi* Gemm. and *Gastrioceras cf. zitteli* Gemm. have been found, which he considers sufficient to correlate the beds, with little doubt, with the Sosio beds of

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[1] Throughout the portion of this paper dealing with China the spelling of names is, so far as possible, in accordance with the revised list giving by Grabau (1923–1924, pages 513–520).

Sicily and the Artinsk of Russia. Near Ningkwohsein, Province of Nanhwei, *Paraceltites pseudo-opalinus* Frech and a form similar to *Gastrioceras* indicate an approximate Artiskian horizon.

Wang (1922), describing the stratigraphy of Paotechore in northwestern Shansi, speaks of a thick series of shales above the Shansi Series which he regards as partly Permian and partly transitional. This is followed by the Kusung Series, 300 meters of red shale and variegated sandstone which, pending the determination of the plant fossils, he regards provisionally as Permo-triassic.

Grabau (1920) has described a lower Permian fauna from the coal basin of Kaiping which he considers identical with the Permian of the valley of Lautsian Kiang described by Loczy.

Norin (1922, 1924) gives a detailed description of the stratigraphy of the region east and west of Taiyuanfu in the Province of Shansi which he divides as follows:

3. Shichienfeng Series. Mainly Triassic.
    - Sand, mostly aeolian.
    - Argillite and marl with calcite.
2. Shihotze Series. Permian.
    - Upper Permian.
        - Zone of *Gingko*. Red-brown argillites with intercalations of sand. Chalcedonic at upper surface.
        - Zone of *Gigantopteris*. Yellowish marl with intercalations of sandstone with an argillite cement of red-brown color (laterite).
    - Lower Permian.
        - Gray-green argillite with intercalations of sandstone.
1. Yeukmenkai Series. Mainly Carboniferous.

Lee considers that the Shansi Series, a division of the Yeukmenkai, is equivalent to the Permo-carboniferous, = Artinskian of Russia, and is transitional to the higher horizons. His interpretation of the lithology of the beds leads him to suggest that there was a continuous desiccation of the climate leading to well-established deserts in the Triassic.

Grabau (1923–1924) gives a somewhat different interpretation of this section—

- Upper Permian.
    - Shichienfeng series.
        - Sandstone and gypsiferous marl.
- Lower Permian (Rothliegende).
    - Shihotze (or Shihotse) series.
        - Upper. Chocolate-colored, sandy argillaceous shale and claystone interbedded with white and yellow sandstone and plant-bearing yellow, yellow-green and dark-green shale. Grabau speaks of this, or part of it, as a laterite.
        - Lower. Light-colored marl, shale and thin sandstone with a lower Permian (Rothliegende) flora. Grabau says, fluviatile marls with thin seams of coal.

Permo-carboniferous.
  Shansi series (*sens. strict.*).
    Shale, sandstone and thin coal. Grabau says, mixed marine and continental.

Willis and Blackwelder (1907) gave the following general column—

Permo-Mesozoic.
  Sintai Formation.
    3. Massive red clays with seams of coarse conglomerate and sometimes of limestone.
    2. Sandy, gray shale with thin strata of sandstone.
    1. Red earthy sandstone strongly crossbedded.
Upper Carboniferous.
  Shansi Poshan Formation.
    2. Shales and sandstone of yellow, brown, gray, and black colors, with local basalt flows.
    1. Coal seams and black limestone in dark shales.

It is apparent that Lee, cited above, includes in his Shansi Series both the Shansi and the Sintai of Willis and Blackwelder. Norin's account is a little difficult to reconcile with other descriptions.

Willis and Blackwelder describe red shales and sandstones with occasional gray limestones as lying in synclines in the Wushan (Carboniferous) limestone in the vicinity of Kuichow (Tsechuen (Szechuan) Province); they call this group of beds the Kuichow Series and regard it as of Permo-Mesozoic age.

The same authors describe the coal-bearing shales and overlying red sandstones (of Shansi and western Chili) as lying in synclinal troughs in the Shansi formation. These are broadly expanded in Shansi as two "terranes":

2. "Thick sequence of light reddish sandstones with subordinate red shales.
1. "Soft shales of varied colors (= Richtofen's Taiyang) with coal seams."

Grabau (1923–1924, page 374) quotes Halle in Norin (1924) as follows—

> "The flora (of the upper Shihotse Series) differs from the European Permian in several important respects. The genus *Callipteris*, which is the most distinctive type of the Permian of Europe, is entirely absent, not only in the Upper Shihotse Series but in all the collections from the supposedly Permian deposits of Shansi. * * * Of conifers, too, not only Zechstein forms are wanting, but hardly any undoubted trace of *Walchia* has been found, though the genus would be expected to occur in any large material of Lower Permian plants."

The quotation further insists upon the peculiarity of the eastern flora in the presence of *Gigantopteris* and *Annularia maxima*. Halle concludes that the difference is "largely due to isolation in different phytogeographical districts."

In summarizing the "Supra-carboniferous continental formations" of China, Grabau (1923–1924, page 393) says—

> "The rocks of this series represent the continental sediments which were deposited over the coal formations in north China. They are of fluviatile and in part eolian origin,

and include conglomerates, sometimes with pebbles several inches in diameter, arkoses, red sandstones, sandy shales, and white sandstones with eolian cross-bedding. Banded sandstones, gray quartzites, and grits also occur. The red-beds and the arkoses indicate that the period during which they were deposited was one of semi-arid, and in part perhaps of desert, climate. This is also shown in the western part of China, where the Supra-carboniferous red-beds include gypsum and rock-salt. Beds of this type constitute the surface rock of large parts of the Red Basin of Szechuan, * * *.

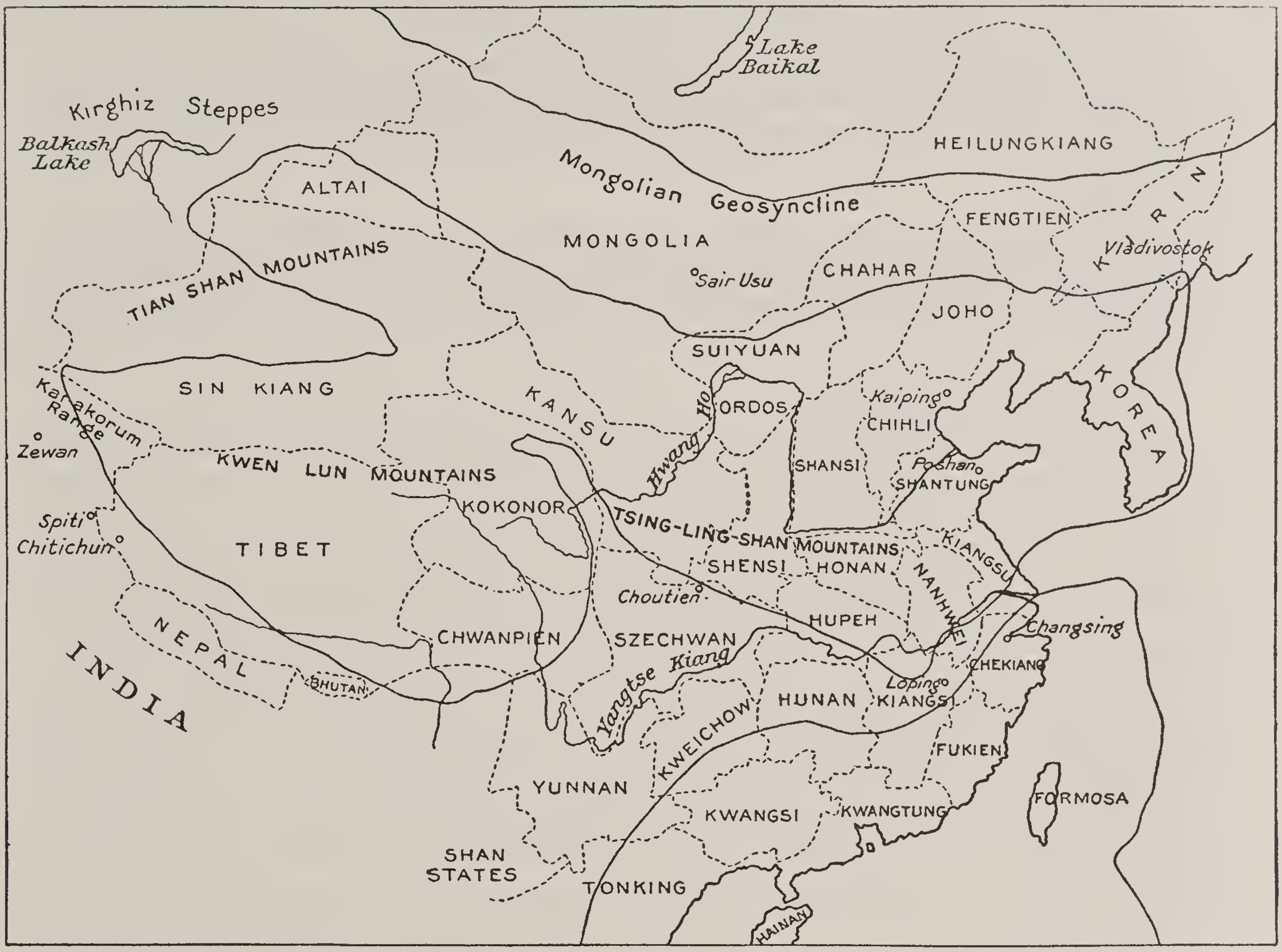

FIG. 15.—Sketch map of China and Mongolia showing localities mentioned. Largely after Grabau.

"The age of these beds is probably in large part Permian, though some portions may represent the deposits during the Permo-Triassic interval, and may be of Mesozoic age. They indicate that toward the close of the Paleozoic, the relatively moist climate of China, under which the coal swamps existed, and the lateritic deposits were formed, was replaced by a dry climate, while the large areas probably became deserts. From this time onward the sea no longer covered north China, though, for a short period in Triassic time, marine conditions were temporarily reestablished, especially in south China."

Permian in Mongolia

Recent reports from the Third Asiatic Expedition of the American Museum of Natural History (Osborn, 1923) record the discovery of a Permian bed by Berkey and Morris in the Sairusi District of Mongolia. Berkey and Morris (1924 [1]) in describing the Gobi region, say—

"Overlying the formations (pre-Cambrian) unconformably are marine limestone, limey shales, and sandstones with fossils of Mississippian, possibly of Pennsylvanian, and certainly of Permian age. All are complexly folded and faulted and have been almost completely swept away in the course of later erosions. Only two comparatively small infolded synclinal and graben-fault remnants of the sedimentary formations of this short-lived, but significant, Paleozoic geosyncline were found in Mongolia. A few dikes cut these beds, but no large intrusions seem to have reached them."

The same authors (1924 [2]) describe these beds as a—

"basal sandstone of only moderate development, with much greater thickness of limestones and shales preserved in downfolded remnants. Several thousand feet in thickness have been seen, but the actual total or maximum thickness is unknown."

Again—

"The larger proportion of the strata is judged by Dr. A. W. Grabau, from the fossil collections made during the first season of the Expedition's work, to be of Permian age, but there is a continuation downward into a still earlier period, at least into the Pennsylvanian."

The authors state that—

"probably marine Paleozoic strata were formerly extensively distributed in central Asiatic region, but the early Mesozoic or mid-Mesozoic epoch of diastrophism and erosion wrought such havoc that now only a few remnants are preserved."

In discussing the results of the work of the Asiatic Expedition, Grabau (1923–24, pages 339–340) says there was a great Mongolian geosyncline in latitude 44° 30′ North and between 107° 30′ North and 108° East. Here Berkey and Morris found *Lyttonia* and other Permian invertebrates. This geosyncline extended east to the Pacific where similar beds occur near Vladivostock. Definitely located beds near Jiso Honquer, 42° 18′ North and 109° 30′ East, carry *Lyttonia.* Grabau considers that this geosyncline was in existence in Middle and Upper Permian connecting China with Europe, and that there was a broad connection to the south as shown by the presence of Indian invertebrates. This southern connection extended to the Russian Basin and even to the Mediterranean, but was subject to intermittent closure as is indicated by the essential differences in the faunas.

The Lower Angara beds of Siberia and Mongolia, so named by Suess, are called the Kusnezk Series by Grabau (1923–24, page 394). He gives a long list of fossil plants of a Mesozoic aspect but notes that the presence of *Noeggerathiopsis hislopi* (Bunbury) indicates a position near the Talchir, Damuda and doubtfully Triassic beds of India. These beds have been traced over many thousand square miles in western Siberia. From the Tarbagatai Mountains on the Russo-Mongolian frontier (between latitudes 47° and 48° and longitudes 82° to 86°), north to the Khatanga River (latitude 105°) near the Arctic coast, and east to the vicinity of Lake Achit in the Valley of Lakes and in the Taunu Ola Mountains, 1,500 miles from the Ekibastus Mines in the Kirghiz Steppes.

There are few forms in the flora which can be definitely identified with forms from the Southern Hemisphere, but the presence of even these few indicates land connections, for at least brief periods, between what were generally separate regions. There is a possibility that the intermigration took place either at the end of the Carboniferous or at the end of the Permian; in the latter case the flora is rather Mesozoic than Permian. (Grabau, 1923–24, page 407 and preceding).

The Paleozoic closed in China with an extensive withdrawal of the sea and there was some slight tectonic disturbance, notably the folding of the Tsinling geosyncline (Grabau, 1923–24, page 408). Grabau gives the following summary of the Permian Paleogeography of China (1923–24, page 498 et seq.).

"* * *. After the final retreat of the waters at the end of the period in which the Taiyuan strata were deposited, the whole of the Chinese territory appears to have become dry land and to have remained so during the greater part, if not the whole, of the Moscovian and Uralian time. If, as has been stated elsewhere, the lower Productus limestone of the Salt Range represents the early Upper Carboniferous, i. e., Gschellian, it marks a temporary readvance of the sea in the Himalayan geosyncline after a long period of non-deposition, which began with the withdrawal of the waters at end of Dinantian time. There is at present no reliable evidence that Moscovian time is represented by marine strata in southern and eastern Asia. None is known from the Himalayan geosyncline, from the Chinese Basin or from the Mongolian geosyncline. The readvance of the sea in Gschellian time, if it took place, seems to have been limited to the Himalayan geosyncline, but it may also have extended into southwestern China and perhaps into Indo-China.

"The first invasion of the Permian sea into China seems to have been restricted to north China, where it is indicated by the marine beds intercalated between the continental systems of the Shansi series. These invasions proceeded through the Nanshan geosyncline, as shown by the Kansu sections. The fauna preserved in the Talapai shales has a decided west European aspect, while typical forms of the Russian Basin are also present. This invasion corresponds approximately to the Artinskian period of the Russian Permian, an horizon which, so far as known, is wholly unrepresented in the deposits of the central part of the Mongolian geosyncline or in those of south China, though certain forms in the Yunnan succession have been referred to the Lower Permian. If these actually belong to this horizon and if, as appears to be the case, the Lower Permian is absent in the Himalayan geosyncline, the Lower Permian beds of southwest China must be regarded as representing an independent invasion from the Indian Ocean of this period. The Shansi series is, however, independent of it and represents an invasion of the north European waters.

"By the close of the Shansi period the sea had permanently withdrawn from the north Chinese Basin where continental sedimentation, however, continued. These continental beds * * * indicate a progressive desiccation of the north China region, until it became a desert basin similar to the Taklamaku basin of the present-day Sinkiang province.

"Meanwhile, at the opening of mid-Permian time, the sea filled the south China Basin and the Mongolian geosyncline, the invasion most probably proceeding from the south and the east, i. e., from the Indo-Pacific province, which was the home of the *Lyttonia* fauna. * * *

"It is most probable that this fauna entered the Chinese Basin from the south, from Indo-China, spreading northward and eastward in the Tsingling and Loping geosynclines, the latter of which opened to the Pacific in the region of the modern Yangtse mouths. It is of course possible that a part of the fauna entered the Loping geosyncline direct from the Pacific opening on the east, though the comparative narrowness of that waterway may have made this more difficult. From South China this fauna spreads westward in the Himalayan geosyncline where it is represented in the middle Productus limestone. The westernmost extension is seen in the Mediterranean region of southern Europe, especially in the Bellerophon limestones of the Alps and Italy. In the southern Alps the Bellerophon limestone carries an abundant fauna which is clearly of the Indo-Pacific type. * * *."

[Grabau here presents arguments showing that the fauna could hardly have entered the Alpine region from the Atlantic—.]

"The Middle Permian lies discordantly upon the Lower, beginning with the polygenetic conglomerates and red sandstones and comprising chiefly marls and red argillites. This series supports concordantly the Upper Permian which consists of dolomites, limestones, and black shales. This section strikingly resembles that found in the southern Alps.

"So far then as our present knowledge of the Permian fauna of the Northern Hemisphere permits us to judge, the fauna may be divided into two groups: The Boreal and the Pacific. The former spread over Europe in early Permian time and also entered the north Chinese region, where it constitutes the Shansi fauna. It was, however, apparently excluded from the Himalayan geosyncline, from south China, and from eastern Mongolia, these regions being dry land at that time. In mid-Permian time, when the Boreal fauna extended into Europe in the Zechstein Sea, the Indo-Pacific waters transgressed widely over southern Asia, entering the south Chinese Basin and Himalayan geosyncline and extending westward into the Mediterranean Basin, which apparently was closed on the west. In these south European regions tectonic disturbances had affected the Lower Permian strata, and the mid-Permian transgression brought a wholly new fauna into this region, this being primarily due to the extension of the Indo-Pacific waters. The transgression of the Boreal Sea, however, permitted a certain admixture of types from that realm, and some of these no doubt became intermingled with the Indo-Pacific fauna in the Asiatic region. * * *.

"After the entrance of the *Lyttonia* fauna into the south Chinese Basin, a gradual transgression set in, the waters spreading over the borders of the *Lyttonia* Basin, thus permitting a progressive overlap of the successive beds of the Middle and Upper Permian. A temporary halt of this transgressive movement was affected at the end of mid-Permian time, when conditions for the formation of extensive coal swamps became widespread in southern China."

This was the period of the formation of the main or Upper Permian coal of south China (Tanshan, Laohu, Lungtan, and perhaps the Leipakou coals). It was followed by a readvance of the sea with a wide distribution

"of cephalopods which spread into Sicily and the Pyrenees. Finally the Permian Sea of south China became again the site of extensive limestone deposits * * *.

"Permian time closed in China, as everywhere else in the world, with a complete withdrawal of the sea and the widespread development of continental conditions, with frequently accompanying aridity of climate."

PERMIAN IN MANCHURIA

The coal fields of Manchuria have afforded a flora which is mostly Westphalian and Stephanian in age, but is supposed by some writers to indicate a Permo-carboniferous age. These coal fields occur at Penhsihu, 40 miles south of Mukden and at Honkeiko and Yentai, all in southern Manchuria.

PERMIAN IN JAPAN

Two series of limestone in Japan have been referred to the Uralian or early Permian. They are exposed at Yajagi in the Kitahami Mountains, which lie in the northern half of the folded area on the Pacific side of northern Japan, on the north and south sides of Sandai Bay. These limestones carry invertebrates of the age assigned.

CHAPTER IX

SUMMARY DESCRIPTION OF THE PERMO-CARBONIFEROUS DEPOSITS OF INDIA AND THE EAST INDIES

The Permo-carboniferous or Permo-triassic deposits of India are divided by the geologists of the Indian Survey into a northern area, called the Extra-peninsular area, and a southern area, called the Peninsular area. The Peninsular area has been consistently a positive region and has been but little disturbed by tectonic movements. The Extra-peninsular area includes the Himalayan and Front Ranges extending from Afghanistan to China and Siam. The much-disturbed series of sedimentary rocks in this area includes representatives of all the geological periods from the Cambrian to the Tertiary.

The Permo-triassic deposits of Peninsular India lie upon the pre-Cambrian and are terrestrial in character; the rocks deposited in the same interval of time in the Extra-peninsular region are marine, except for a limited thickness of terrestrial material at the base of the series in Kashmir. The two regions have had radically different histories and the conditions of life in the two were equally different.

The succession of rocks in India is divided by the geologists of the Survey into four great groups:

Aryan, all post-Paleozoic deposits.
Dravidian, Cambrian to Carboniferous, inclusive.
Purana, equivalent to the Proterozoic.
Vedic, equivalent to the Archeozoic; this is the Archaean of Waida (1919).

In the Peninsular area the lowest beds of the Aryan Division, the Gondwana System, lie unconformably upon the pre-Cambrian. As the area has been but little disturbed the rocks appear in separated patches which are probably parts of once much larger areas, possibly united into a nearly continuous whole, which covered much of the peninsula. The whole series is terrestrial in origin, fluviatile, lacustrine, palustrine, aeolian and glacial.

The Gondwana System is usually divided into an upper and a lower part; in some places, as in western Bengal, there is a decided unconformity between the two, but in general the passage from one to the other is without break. Waida (1919) gives a general survey of the beds in the different separate patches. (See page 127.)

Reed, in his summary account of the geology of India (1921, pages 281–283), gives an account which shows a two-fold rather than a three-fold division of the beds; it is here put into tabular form. (See page 128.)

The lower Gondwana is considered as Carboniferous and Permian. The Upper Gondwana as Triassic and Jurassic; the Jablapur and Umia beds reaching to the Neocomian.

	System, Series.	Damuda Valley.	Rajmahal.	Son and Mahandi Valleys.	Satpura.	Godavari.	East Coast.	Cutch.	Age.
U. Gondwana	Umia						Tripetty, Pavalur, etc.	Umia	Portlandian.
	Jablapur			Jablapur	Jablapur, Bagia.	Chikiala, Kota	Raghavapurum, Sripermatur, etc.		Bathonian.
	Rajmahal	Rajmahal	Rajmahal				Golapilli and Budavada stage.		Lias.
M. Gondwana	Maleri or Denwa				Maleri or Denwa.	Maleri			Keuper.
	Kamthi or Pachmahari.	Kamthi	Dubrajpur sandstone.	Kamthi	Kamthi or Pachmahari.	Kamthi or Mangli.			Muschelkalk.
	Panchet	Panchet							Bunter.
Lower Gondwana	Damuda	Raniganj stage.			Bijori				Upper Permian.
		Ironstone shale stage.							
		Barakar stage.	Barakar	Barakar	Barakar or Motur.	Barakar			Middle Permian.
	Talchir	Karharbari stage.		Karharbari	Karharbari				
		Talchir stage.	Talchir	Talchir	Talchir	Talchir			Permo-carboniferous.

Arrangement of the Indian Permian and Permo-triassec beds. After Waida.

The Raghavapuram shales are described by Reed as marine intercalations in the Rajmahal horizon and the Trippety beds as marine intercalations in the Jablapur horizon. The Bijori stage of Medlicott is in large part equivalent to the Raniganj stage; the upper portion, the Almod beds, is perhaps equivalent to the Panchet.

		Bengal.	Satpura.	Rajmahal.	Godavari Valley.
Upper Gondwana	Jablapur beds. Kota-Maleri beds.		Kota-Maleri. (Belong in part to Rajmahal series.)		Kota-Maleri. (Belong in part to Rajmahal series.)
	Rajmahal series.			Rajmahal series. Unconformity.	
	Makadeva series.			Dubrajpur sandstone.	
		Stratigraphic and paleontological break.			
Lower Gondwana	Panchet series.		Maleri series. Kamthi series.		
	Slight unconformity.				
	Damuda series.	Raniganj stage. Ironstone shale stage. Barakar stage.			
	Talchir series.	Karharbari series. Upper beds of Talchir series.			

Arrangement of the Indian Permain and Permo-triassec beds. After Reed.

Ball (revised by Simpson, 1913) describes the Talchir beds as follows:

> "The Talchir beds consist in general of fine, silty shales and fine, soft sandstones. The shales are usually greenish gray or olive in colour, and are traversed by innumerable joints. The sandstones are fine, even-grained and vary in colour from olive to pale pink. They are composed chiefly of quartz and undecomposed pink feldspar. A thin coal seam occurs amongst the Talchir beds in the Jhilmilli coal field in Sarguja, but as a rule these beds do not contain coal seams. Toward the base of the group a remarkable boulder-bed containing striated pebbles points to the existence of glacial conditions in early Gondwana times. * * * The Talchirs attain their greatest development in the Raniganj coal field, where their thickness is about 800 feet."

The same authors describe the Karharbari rocks as resting conformably upon the Talchir and reaching a thickness of 800 feet in the Giridih coal field. These beds are recognizable in most of the coal areas of the peninsula. They are described as consisting of white, gray or brown felspathic sandstones, grits and conglomerates, with coal seams associated with a little shale.

> "The fragments of the feldspar and quartz are, as a rule, angular and sub-angular, and are thus sharply distinguished from the typical Barakars (above) which are usually well rounded."

Reed (1921) says of the conglomerate—

"This boulder-bed contains pebbles and boulders from a quarter of an inch to 15 feet in diameter, irregularly distributed in the matrix; they are always rolled and usually well rounded, and may be faceted, scratched, or smoothed on some faces; and the underlying rock is in some places scored and polished. The glacial origin of this boulder-bed or tillite is now generally admitted. The rest of the Talchir Series consists of sandstones and grits rarely containing a few plant remains, including the typical genera *Glossopteris* and *Gangmopteris.* The thickness of the group is not above 800 feet.

"In the Karharbari coal field, Bengal, the upper beds of the Talchir Series are sometimes designated the Karharbari Series and here contain valuable seams of coal. Fossil plants are numerous, including species of the two above-mentioned genera (*Gangmopteris cyclopteroides, Gl. indica*), and *Noeggerathiopsis hislopi*, etc."

As shown in the table given on page 127, Waida (1919) divides the Talchir into two stages—

"The lower, the *Talchir stage*, has a wide geographical prevalence, and is present in all the localities where Gondwana rocks are found, from the Rajmahal Hills to the Godavari and from Raniganj to Nagpur. The group is quite homogeneous and uniform in composition over all these areas, and thus constitutes a valuable stratigraphical horizon. The component rocks (300 to 400 feet thick) are green laminated shales and soft fine sandstones. The sandstones contained *undecomposed* felspar grains, a fact which suggests the prevalence of land-ice and the disruptive action of frost. Glacial conditions are, however, more clearly indicated by a boulder-bed, also of very wide prevalence in all the Gondwana areas, containing the characteristically glaciated, striated and facetted blocks of rock brought from afar and embedded in a fine silt matrix. The presence of fine silty matrix suggests *fluvio-glacial* agency of transport and deposition rather than glacial. The boulders and blocks were transported in floating blocks of ice, and dropped in the Talchir basins, in which the deposition of fine silt was going on. Proofs of similar conditions at this stage (Permian) exist in many other parts of India, viz, The Arvallis, Rajputana, Salt Range, etc. The Arvallis, it appears, were the chief gathering grounds for the snow fields at this time, from which the glaciers radiated out in all directions.

"Fossils are few in the Talchir stage, the lower beds being quite unfossiliferous, while only a few remains of terrestrial organisms are contained in the upper sandstones; there are impressions of the fronds of the most typical ferns, *Gangmopteris* and *Glossopteris*; wings of insects, worm tracks, etc., are the only signs of animal life. The Talchir stage is succeeded by a group of coal-bearing strata known as the *Karharbari stage*, 500 to 600 feet in thickness, also of wide geographical prevalence. The rocks are grits, conglomerates, felspathic sandstones and a few shales, containing seams of coal. Plant fossils are numerous, the chief genera being: (Ferns) *Gangmopteris*—eight species; *Glossopteris*—two species; and *Sagenopteris*; (Equisetums) *Vertebraria, Schizoneura* (like *Calamites*); (Conifers) *Voltzia* and *Albertia.* Besides leaves of these plants there occur some fossils seed-cases and fruits and a large number of stalks or stems of equisetums."

The Barakar stage, at the bottom of the Damuda Series, is the most widely dispersed of the Upper Series. It occurs not only in Bengal but in the valleys of the Godavari, Mahandi, and Satpura Rivers. This stage consists of "coarse, soft, usually white, massive sandstone and shales with coal seams," lying unconformably upon the Talchir. Deposits of this stage reach a thickness of 2,000 to 3,300 feet in the Damuda Valley. Ball and Simpson (1913) describe the Barakar stage as composed of sandstone, conglomerate, shale and coal. The sandstone is soft, coarse and felspathic;

the conglomerates have rounded pebbles as opposed to the angular fragments of the Talchir below; the dominant color of the beds is white, but there is some banding; the shales are gray, blue or black, usually arenaceous, sometimes micaceous.

The second stage, the Ironstone Shale, is composed of a mass of carbonaceous shale with concretions of sphaerosiderite and some iron oxide; the concretions occur as lenticular bands and nodules, sometimes passing into "black band." This phase of the Damuda stage occurs only in the Damuda region and is variable in thickness and occurrence.

The uppermost stage, the Raniganj, is of wide occurrence in the Peninsular region. The rocks are chiefly sandstone—massive, false-bedded, and coarse, varying to fine, in grain, white or brown in color, and filled with undecomposed felspar. The shales are gray, red, brown or black, occasionally ferruginous, with many coal seams. The Damuda series in Bengal reaches a thickness of 8,400 feet. According to Waida, the Damuda series is represented in the Satpura region by 10,000 feet of sandstone and shale divided into the Barakar, Motur and Bijori stages, equivalent to the Barakar and Raniganj of Bengal. He considers it probable that a much wider extent of these beds lie beneath the basaltic flows of the Satpura region.

The Damuda Series, Barakar stage, is recognizable in the coal fields of the Godavari Valley from Waroia to Rajahmundri; in the Rewa province of Central India there is a small area of Barakar beds with some coal.

The Panchet Series, listed by Waida as the lowermost of the Middle Gondwana and by Reed as the uppermost of the Lower Gondwana, is separated by a slight unconformity and a much more marked change in facies and fauna from the Damuda below. The rocks are coarse, red, felspathic sandstones, conspicuously cross-bedded and with interbedded red clays and shales. The felspar of the sandstone is fresh and there is much mica (Waida, 1919). No coal seams have been found in the Panchet. The decided change in the material of the beds, the method of deposition and especially the fauna leaves no question that the Panchet is Triassic in age.

The Extra-Peninsular area in India is largely made up of rocks of marine origin but there are beds of terrestrial origin which are all important in tracing the movements and relations of the land vertebrate life of the late Paleozoic.

In northwestern Afghanistan there is a mass of coal-bearing sandstone which is believed to be of Gondwana age. It terminates below in a shale which has been altered to a mica schist with seams of graphite, anthracite and impure limestone. The lower portion of the series includes a succession of coarse conglomeratic or boulder beds which resembles the Talchir glacial conglomerate of the Peninsular area. Above, the beds pass into a series of sandstones, limestones and shales with marine fossil of Triassic age (*Halobia*, etc.); at the bottom certain of the sandstone carry beds of coal with impressions of plants. (See Griesbach, 1886.)

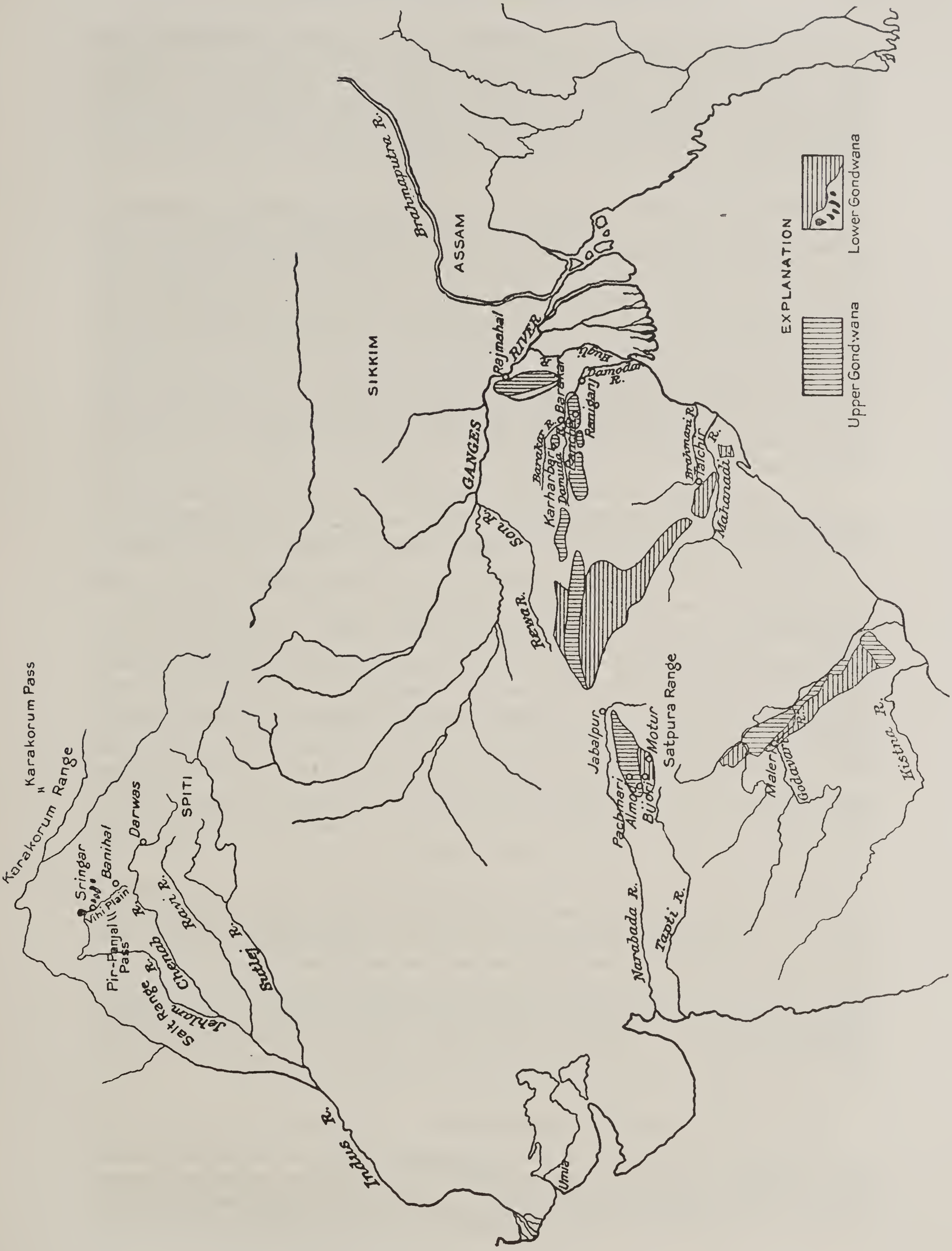

FIG. 16.—Sketch map of India showing localities mentioned.

In the Salt Range the lower part of the Permian (Dravidian stage, Speckled Sandstone Series) is formed by a fine-grained, greenish, shaly or sandy matrix which contains boulders that are sub-angular, striated, facetted and of unequal size; these come very largely from the south, the Arvalli Range. Reed (1921) summarizes the accounts of this deposit as follows—

> "Occasionally beds of sand or conglomerate are found interstratified and splitting up the boulder bed. The general character of the deposit, the striations and faceting of the boulders, the nature of the matrix, and the absence of stratification and sorting as well as the occasionally striated surface of the solid rock on which the bed rests, point unmistakably to a glacial origin. The beds immediately associated with and conformably overlying the boulder-bed contain an Upper Carboniferous or Permo-Carboniferous marine fauna, including many species found in similarly placed beds in Australia (*q. v.*), associated also with a boulder-bed having identical characters; and some of the same species have recently been found in the Dwyka Series of South-West Africa. The identical species occurring in India and Australia include the mollusca *Eurydesma globosum*, *E. cordatum*, *Conularia laevigata*, *C. tenuistriata*, *Pleurotomaria nuda* and the brachiopod *Spirifer* (*Martinopsis*) *darwini*.
>
> "The boulder-bed in the Salt Range varies from 20 to 150 feet in thickness, and the associated olive sandstones, clays, red shales, and red and purple sandstone, which overlie it and contain the above fauna in their lower portion, possess a thickness of 400 to 500 feet."

In the central Himalayas, as described by Diener (1912), the lower part of the Permian or Permo-triassic, the Kuling System, is formed by a conglomerate—"but not a boulder bed" (Reed, 1921)—resting unconformably upon the upper Carboniferous. According to Waida (1919) and Reed (1921) this is followed by a calcareous sandstone with the fauna of the Productus limestone. Waida quotes a table from Hayden showing a series of grits and quartzites between the conglomerate and the calcareous sandstone. In Kashmir a series of basic lava sheets totaling several thousand feet in thickness directly overlies the Upper Carboniferous, unconformably; interbedded with the lava sheets are slates and, especially noteworthy, the "agglomeratic slates." Reed (1921) describes them as—

> "a dark-grey fine grit, containing angular fragments of quartz, felspar, slate, quartzite, porphyry, pegmatite, and granite, from the size of a pea to that of a piece several inches in diameter. No striation or facetting has been noticed on any of these fragments. The slate is interbanded with some quartzites, and has thick bedded traps above. Its mode of formation is uncertain, but it may be of the same age as the boulder-bed at the base of the Permo-Carboniferous in the Salt Range, and as the Talchir conglomerate at the base of the Gondwana System in the Peninsula. At any rate its characters indicate a period of disturbance and a cessation in the deposition of marine sediments, but there is no clear evidence of ice-action."

Waida (1919) says of this agglomerate—

> "Much of it is composed of a fine greywacke-like matrix with embedded angular grains of quartz. But the rock does not appear to be an ordinary sedimentary deposit inasmuch as the embedded fragments are quite angular and often become very large in size at random. They are pieces of quartz, porphyry, tourmaline-granite, slate, etc., irregu-

> larly dispersed in a fine-grained matrix. The matrix is also of a doubtful description, suggesting neither in its structure nor aspect any definite mode of formation. For aught one can say from its appearance, it might have been a volcanic ash or glacial mud just as much as ordinary clastic clay. The rock is generally unfossiliferous throughout though recently at a few localities several interesting suites of fossils have been discovered by Middlemiss and the late Mr. Bion, which are identical with forms entombed in the underlying Fenestella series. That such a rock could not have been the product of any simple process of sedimentation, whether subaerial or submarine, is quite clear, and the origin of the deposit so widespread and of such uniform character is a problem.
>
> "One view is that the rock is a joint product of explosive volcanic action, combined with ordinary subaerial deposition; the other, a diametrically opposite view, is that it is due to frost action under glacial or arctic conditions, the frost-weathered debris being subsequently transported by floating ice-masses to lakes. Middlemiss favors the former view, as being more in keeping with the actual circumstances of the case and as congruent with the lava eruptions that succeeded it; though he points out that the absence of glass-particles, pumice fragments, and other products usually associated with tuffs, is irreconcilable with this view. The presence of Lower Gondwana plants in beds immediately overlying the volcanics favours the inference that the slate-conglomerate is a glacial deposit corresponding to the Talchir boulder-beds. No facetted or striated pebbles are, however, found in the slates, which, on the contrary, are frequently quite angular."

In his table Waida places this layer at the top of the Dravidian stage and below the Aryan, therefore rather Upper Carboniferous than lower Permian, where he places the Talchir.

The Panjal volcanics are directly followed by a series of siliceous and carbonaceous shales which carry the *Glossopteris* and *Gangmopteris* floras. These are best displayed in the vicinity of the Pir Panjal and the Vihi Plain lying but a little south of Sringar. The beds are composed (Waida, 1919)—

> "of a variable thickness of cherts, siliceous shales, carbonaceous shales, thin-bedded limestones and flaggy siliceous beds of quartzite. The thickness varies from a few feet at some of the Vihi outcrops to some hundreds of feet in the outcrop of the Panjal Range."

The typical section from the Golabgarh Pass, as given by Middlemiss (1909) is—

Zewan series.	Protoreteopora limestone.		Permian.
Gangmopteris beds.	Earthy sandstone, calcareous above, passing into Zewan limestone.	230 feet.	Lower Gondwana (Permo-Carboniferous).
	Hard, compact black shales with *Glossopteris*; hard grey sandstone and interbedded shales with *Psygmophyllum*, *Gangmopteris*, and *Vertebraria*.	400 feet.	
	Thin-bedded, buff-colored, compact siliceous and carbonaceous shales.	180 feet.	
	Basal conglomerates.	60 feet.	
	Panjal traps and ash-beds.		Upper Carboniferous.

Waida (1919) gives the general comparative section—

Kashmir.	Spiti.	Salt Range.	Age.
Zewan series, 300 feet	Productus shales	Productus limestone	Permian.
Gangmopteris beds, 800 feet. Equal to Talchir and Karharbari.	Permian conglomerate.	Speckled sandstone Boulder-bed.	Permo-Carboniferous.
Panjal traps. Panjal agglomerate slates.			

Reed (1921) mentions "outlying patches" of Permian or Permo-Triassic in Assam and Sikkim and compares them with the deposits in Kashmir and Afghanistan. (It is not clear whether he refers here to terrestrial deposits or has in mind a northerly extension of something like the Plateau Limestone of the Burmese region.)

The marine deposits of India and adjacent territory show the general outline of the shore and reveal, in part, the history of the great Tethys Sea. The subjoined table assembled from the work of various authors indicates the general relations and sections in different regions. The descriptions in the table are sufficient for this work which is primarily concerned with the terrestrial phase of the development in the late Paleozoic.

		Salt Range.	Kashmir.	Himalayas.	Burma and Assam.	Age.
Productus limestone Ammonites present.	Upper,Chideru.	Chideru stage. Marl and sandstone. Kundghat stage. Sandstone with *Bellerophon*. Jabi stage. Cherty limestone.			Upper Plateau limestone. Fusulina and Productus limestone. Partly dolomitic and brecciated. Mainly unfossiliferous.	Marine Neo Dyas. Zechstein. Thuringian.
	Middle, Virgal.	Kalabagh stage. Crinoidal limestone with marl and dolomite. Virgal stage. Cherty limestone.	Zewan beds.	Chitichun limestone and Kuling shales of Spiti.		
	Lower, Amb.	Katta stage. Arenaceous limestone and calcareous sandstone. Amb stage. Calcareous sandstone.		Productus shale (calcareous) of Lilinthi.		MarinePaleo-Dyas. Saxonian (?)
Punjabian (Speckled sandstone) No Ammonites.	Wartha.	Middle speckled sandstone.				Glacial and post glacial Paleo-Dyas, Rothliegende.
	Dandote.	Lower speckled sandstone. Lower part fossiliferous.				
	Talchir.	Tillite, with boulders.	Gangmopteris beds (Karharbari and Talchir).	Conglomerate (not boulder bed) at base.		
			Panjal traps and agglomerate slate.			

Traces of the Permo-Carboniferous Between India and Australia

So little is known of the detailed geology of the eastern side of the Bay of Bengal that it is impossible to do more than draw very tentative conclusions, other than the important one of the presence of an efficient barrier to any migration of tetrapod vertebrates between Australia and the Indo-African land mass.

In Burmah there is a considerable thickness of fossiliferous limestone, the Plateau Limestone, which is correlated by its fauna with the Productus limestones and shales of the Salt Range and Spiti, and the Zewan beds of Kashmir.

In the Malay Pennsula there is a series of marine and terrestrial beds, grouped under the name of the Pahang Volcanic Series, which is generally considered to be of Carboniferous and Permo-Carboniferous age. According to Scrivenor (1913) and Reed (1921), the Pahang Series may be divided into an upper, terrestrial group, the Tembeling series, equivalent to the Gondwana of India, and a lower, marine series, the Raub series.

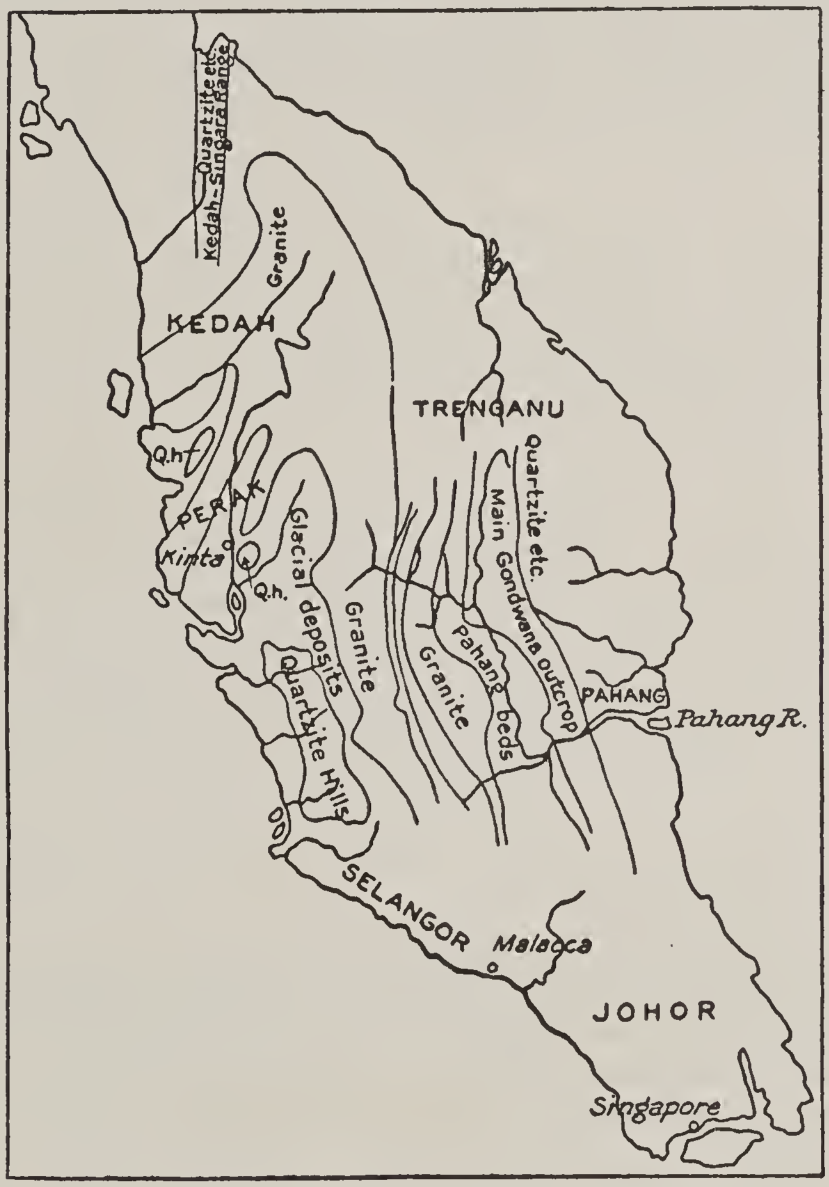

Fig. 17.—Sketch map of Malay Peninsula showing localities mentioned.

According to Reed's summary the Raub series forms much of the low-lying ground and is best seen in the valley of the Pahang River. The limestone member of the series is crystalline, white, gray, black or reddish in color; other members are shale with volcanic ash. The calcareous shale carries a fauna similar to that of the Productus limestone of the Extra-peninsular area of India and the limestones and shales of the East Indies; Reed suggests that it may be a continuation of the Fusulina limestone of Sumatra and the Permo-carboniferous beds of Timor and Rotti. The volcanics of the Pahang series are interbedded with the limestone of the Raub series, but are continued into Tembeling time.

The Tembeling series lies unconformably upon the Raub; it is made up of quartzites, grit, shale, claystone and conglomerate. In the basal portion of the series are the Kinta clays, the "Gopeng beds," with many boulders of various kinds and sizes lying on an irregular limestone surface. These are the beds which Scrivenor regarded as equivalent to the Talchir of India, a suggestion which has been questioned by other workers in the region. Certain quartzites, phyllites, carbonaceous slates and schists of the Kinta Valley have been associated with these beds and referred to the Gondwana System; they have a wide extension in Perak and Silangor, but are unfossiliferous except in north Perak, where they carry an *Estherella* of "Triassic affinities." Above them lies the Myophora-sandstone, very similar in its fauna to some of the European Rhaetic horizons.

The following quotations from Scrivenor (1913) will give an idea of his conception of the old land border in the Malay Peninsula.

> [Page 348.] "The oldest known rocks *in situ* are a calcareous series, named provisionally the Raub series, with which is associated in Pahang, the Pahang Volcanic series, partly contemporaneous with the Raub Series, but continuing unto later time.
>
> "Unconformable to the Raub Series is a great development of littoral rocks—quartzite, conglomerate, shale, clay-slates, and phyllites formed by metamorphism of the shales. Some rocks of the Pahang Volcanic Series are contemporaneous with part of them. In the Kinta district of Perak, and in other localities, at the base of these littoral rocks is a considerable thickness (about 200 feet where best preserved) of stanniferous clays with boulders, believed to be of glacial origin. The quartzites, etc., form a large part of the hilly country of the Peninsula, and they, together with the glacial clays, will be referred to collectively as the Gondwana rocks."
>
> [Page 349.] "Apart from the glacial clays, these rocks are best seen in Pahang, where fossils have been found near Kuala Lipis and on the Benta-Kuantan road, but the fossils have also been found in Perak and Singapore. At first, these rocks were called provisionally the Tembeling Series. They consist of conglomerate, quartzite, grit, shale and clay-slate. The two first-named rocks contain pebbles of radiolarian chert. The quartzite is very largely weathered back to sandstone, and the 'Myophorian Sandstone' of Mr. R. N. Newton belongs to this group."

Mr. Scrivenor discusses the age and correlation of the glacial beds in the different areas of the Southern Hemisphere and decides that the glacial horizon is a good time, or at least condition, marker and may be "anything from the Upper Carboniferous to the Permian, more probably nearer the latter." From such paleontological evidence as exists Mr. Scrivenor concludes that the—

"evidence afforded by those (fossils) that have been collected, coupled with the climatic evidence of the Gopeng Bed seems to me sufficient for the belief that we have here an extension of the Gondwana System of India. It is not claimed that the circumstances of the formation of the Malayan rocks were identical with those under which the mass of the Gondwana System was laid down. That is clearly impossible, seeing that, although there is some petrological similarity, the Malayan rocks have yielded many distinctively marine forms; while the bulk of the Gondwana deposits of India have yielded land forms and plants only * * *. The Malayan rocks appear to have been deposited under very much the same circumstances as the Ragavarum (Raghavapurum), Tripetty, Vemavarum, and Sripermatur Beds of the Gondwana System of the eastern coast of India, in which marine organisms occur together with plant remains."

[Page 357.] "This hypothesis, namely, that of the Gondwana coast-line advancing from west to east, has been adopted, in order to explain the occurrence of the glacial rocks in Perak and the Rhaetic horizon in Pahang."

[Page 368.] "At the base of the Gondwana rocks are glacial deposits, which may be referred to the same horizon as the late Paleozoic glacial deposits of Peninsular India, the Salt Range, Australia and South Africa; but this horizon can not be defined exactly in terms of the European sequence. Its presence shows that the Raub Series must be older than the Productus Beds of the Salt Range, or equivalent to the shales below the boulder-bed in the trans-Indus section of the Salt Range.

"The glacial deposits are succeeded by littoral deposits, and a long way east of the former a Rhaetic horizon has been described in the latter by Mr. R. N. Newton, and named by him the Myophoran Sandstone. To account for this apparent discrepancy in age between the climatic horizon afforded by the glacial deposits and the Myophoran Sandstone, an hypothesis has been adopted to the effect that the Malayan Gondwana rocks were deposited on the Gondwana coast line as it moved slowly eastwards, probably with many checks and oscillations."

The studies of the Dutch geologists in the East Indies have revealed a considerable thickness of marine sediment in the islands of Sumatra, Ceram and Timor, and the small islands of the Timor row. There is no trace of glacial beds or of terrestrial sediments. Similar marine sediments have been reported from the central range and from the Northwest Peninsula of New Guinea. It is probable, from all occurrences, that this deposit was originally widely spread over Borneo and the Celebes. The fossils found in these beds have the same general facies as those found in the marine strata of Sicily, the Salt Range, the Himalayas, the Urals, and the southwestern part of the United States. It is altogether probable from such evidence as is now at hand that there was no land connection between Australia and the Indo-African mass in the time of the development of tetrapod life in the late Paleozoic.

The following quotations taken from Brouwer's *Geology of the Netherlands East-Indies* (1925) will give an idea of the nature of this evidence.

[Page 13.] "Sumatra. The first fossils of the Upper Paleozoic were found in the Highlands of Padang in Sumatra. They were first considered as Lower Carboniferous. Later they were called Upper Carboniferous, and at the present time some authors consider them to be of Permian age, on account of the similarity of their Fusulinidae to those of the Permian in Indo-China. All along the western part of Sumatra there is a series of slates and phyllitic slates, sandstones, conglomerates, quartzites, greywackes, cherts, limestones and at many places metamorphic sediments such as hornfels, marbles, mica schists and horneblende or serpentine schists. (A list of invertebrate fossils follows.)

* * *

"It is possible that this important series of rocks of great thickness includes Permian, Carboniferous and even older Paleozoic rocks. (It is of interest to state that in British Malay a series of sediments has been described with a contemporaneous series of volcanic and hypabyssal rocks ranging from rhyloites to dolerites, in which agglomerates and tuffs are particularly widespread. Extensive calcareous shales and limestones are said to have yielded a definite Visean fauna in the Kuantan district of Padang, and Carboniferous fossils are found elsewhere)."

[Page 14.] "In the portion of West Sumatra which belongs to Djambi, two distinct series of Permian rocks have been identified. The two series are found close together, having been brought into this position by large overthrusts. The first series consists of diabases, porphyrites, porphyries, quartz porphyries, melaphyres and their tuffs, with lenses and layers of fossiliferous limestone. The basic lavas and tuffs are found in the lower part of the series and are of the same age as the fossiliferous rocks from the Highlands of Padang, which had formerly been considered as Upper Carboniferous in age. According to Tobler, the Fusulinidae (*Verbeekina verbeeki*, *Fusulinella* sp., and *Neoschwagerina annae*) point to their age as being in the upper part of the Lower Permian. The acid lavas and tuffs are found in the upper part of the series and their age would therefore be Upper Permian. The second series, which has a thickness of at least 1,400 meters, consists of porphyries and quartz porphyries, keratophyres and quartz-keratophyres with their tufaceous sandstones and thick beds of conglomerates in which the pebbles are of the same volcanic rocks. In their layers of limestone in the lower part of the series, Fusulinidae and *Productus* have been found which are considered as cöeval with the Middle Productus limestone of the Salt Range. The upper part of the series may even be Mesozoic in age. Locally thin coal beds, *Cordaites* and *Pecopteris*, have been found in the lower part of the series."

[Page 14.] "The Timor-Ceram Row of Islands. * * * The beds, the greater part of which are undoubtedly properly referred to the Permian, are strongly folded and faulted tuffs, tufaceous marls, marls, limestones and basic effusive rocks." (An exceedingly rich fauna of marine invertebrates has been found in Timor.)

[Page 16.] "On the basis of the ammonites the following stratigraphy has been established:

	Locality.	
	Timor.	India.
Neodyas	Amarassi.	Upper. Productus limestone. Middle.
Paleodyas	Basleo. Bitauni. Astabe.	Upper Artinsk Series.
Upper Carboniferous	Somohole. ?	Lower Artinsk Series.

[Page 17] "The nearest relatives of all the Permian faunas investigated up to the present time are to be found in the Permian of the Alps, of Sicily, of the Urals, of the Salt Range, and in the Himalayas, while the Permian sediments of Timor also correspond to a marked degree with the Wichita formation of North America. We thus see that the Tethys geosyncline, which is usually thought of as being most characteristic of Mesozoic time, was well marked in the Permian and extended from the Mediterranean area to the East Indian Archipelago. But a certain independence appears in the development of the faunas, so that the connection between them was not always open. This is not surprising because littoral sediments were the principal deposits formed in this geosyncline during Permian time.

"The presence of fossiliferous Permian beds has also been noted in other islands of the Timor row (Savu, Rotti, Letti, Luang and Babber). On Letti, an island to the east of Timor, the Permian rocks are greywackes, shales, sandstones and limestones. A series of metamorphic sediments and basic eruptives found here are also supposed to be of Permian age. The fossils * * * are supposed to belong to the lowest part of the Permian. It is a matter of stratigraphical importance that similar, if not identical, ammonites are found in the Irwin River coal field in Western Australia. * * *."

[Page 17.] "Other Late Paleozoic Areas. In New Guinea Paleozoic rocks, which are in part of Permian age, occur in the high central range and in the northwestern peninsula. They consist of sandstones, shales, marls, and limestones with corals, crinoids, brachiopods and trilobites.

"Partly metamorphosed rocks, such as have been mentioned from Sumatra, are of widespread occurrence on the larger islands of Borneo and Celebes and on several of the smaller islands, particularly Ceram and Buru. As to whether these rocks are partly of Permian and Carboniferous age, the same considerations as those given with regard to the older Paleozoic rocks are applicable.

"From what has been stated above, it is evident that Upper Paleozoic rocks, and particularly Permian, are widespread in the East Indian Archipelago. But in many places the age of the beds is still uncertain and the data are not yet sufficiently complete to indicate where the boundary line of the Permian is to be drawn.

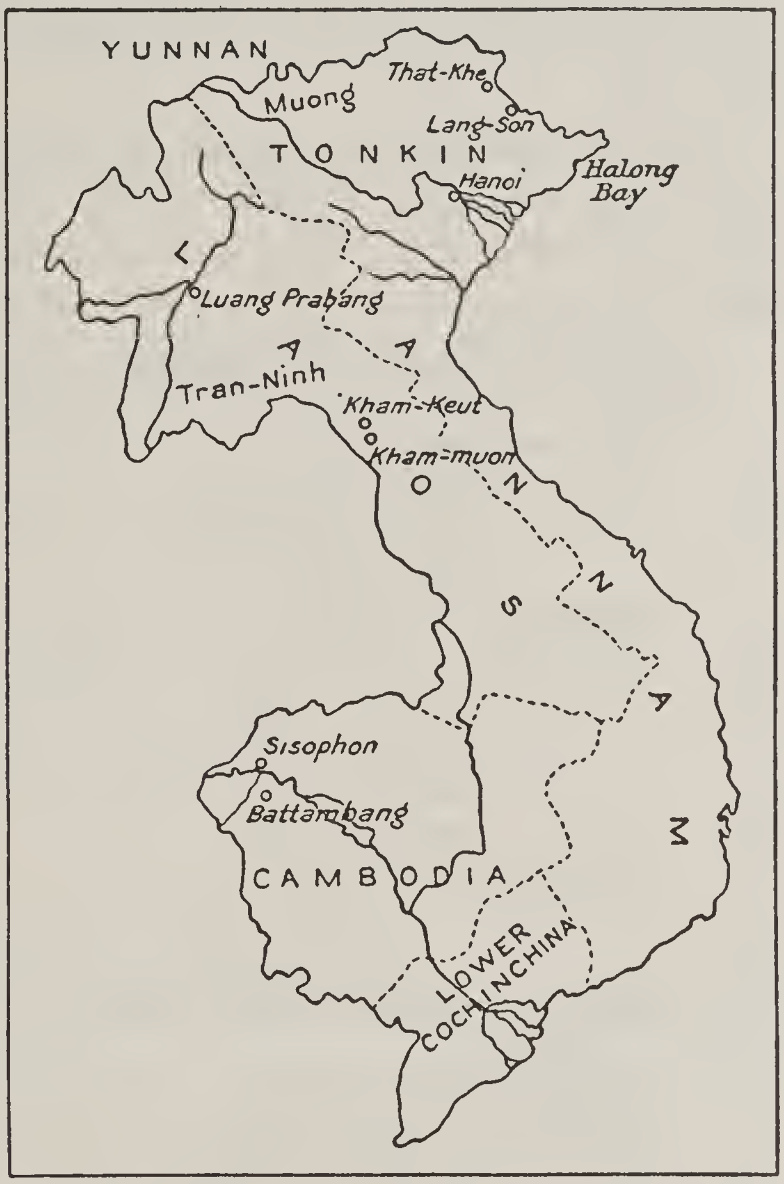

Fig. 18.—Sketch map of French Indo-China showing localities mentioned.

"Glacial beds, which are so wonderfully developed in India and Australia, have not been found among the upper Paleozoic rocks of the East Indies."

Permian Deposits of Indo-China

Mansuy (1908, 1912, 1916, 1919, 1920) and his associates, Giraud (1918), Colani (1919), Dursault (1919) and Jacob and Dursault (1925), have demonstrated the presence of marine deposits in Indo-China, carrying a fauna very similar to that of the Productus limestone of India and the Uralo-Permian beds of Timan and the Ural region of Russia. This limestone enters Indo-China from Yunnan and can be traced down the plateau of Laos into Cambodia, where it was found by Jacob at Battambang and Sisophon. On the borders of Yunnan the limestone changes into shale in which *Glossopteris indica* and *Schizoneura gondwanensis* have been found. Jacob here recognizes a transition from the lower to the upper beds which he considers equivalent to the change from lower to upper Gondwana in India. Mansuy has recorded the discovery of bones from near Luang-Prabang. These occur in a variegated clay with conglomerates of dominantly calcareous elements (*Neoschwagerina globoso* limestone), with silicified wood.

Repelin (1923) has described the specimen as *Dicynodon incisivum.* It is a somewhat imperfect skull coming from beds considered as Triassic by Jacob and Dursault (1925), but is sufficient to show the presence of the South African fauna in southeastern Asia in Triassic time.

Faunal List of the Indian Region:
- Pisces:
  - (From the Kota beds.)
    - Ceratodus hislopianus Oldh.
      - hunterianus Oldh.
      - virapa Oldh.
    - Dapedius egertoni Syk.
    - Lepidotus breviceps Edg.
      - calcaratus Edg.
      - deccanensis Edg.
      - longiceps Edg.
      - pachylepis Edg.
    - Tetragonolepis analis Edg.
      - oldhami Edg.
      - rugosus Edg.
  - (From the Productus limestone, Salt Range.)
    - Acrodus flemingi De Kon.
    - Helodopsis elongata Waag.
      - abbreviata Waag.
    - Petalorhynchus indicus Waag.
    - Poecilodus paradoxus Waag
    - Psammodus sp.
    - Psephodus indicus Waag.
    - Sauricthys (?) indicus De Kon.
    - Sigmodus dubius Waag.
    - Thaumatacanthus blanfordi Waag.
    - Xystracanthus giganteus Waag.
      - gracilis Waag.
      - major Waag.

Pisces—*Cont.*
  - (From Kashmir.)
    - Amblypterus kashmirensis S.-W.
      - symmetricus S.-W.
- Amphibia:
  - Archegosaurus ornatus S.-W. Kashmir.
  - Brachyops laticeps Ow. India, Mangli stage.
  - Glyptognathus fragilis Lyd. Panchet stage.
  - Gondwanosaurus bijorensis Lyd. Bijori stage.
  - Gonioglyptus longirostris Hux. Panchet stage.
    - huxleyi Lyd. Panchet stage.
    - kokeni Huene. Panchet stage.
  - Mastodonsaurus indicus Lyd. Dinwa stage.
  - Pachygonia incurvata Hux. Panchet stage.
- Reptilia:
  - Lystrosaurus orientalis Huxley. Panchet stage.
  - Dicynodon inciscivum Repelin. Indo-China, Laos.

CHAPTER X

SUMMARY DESCRIPTION OF PERMIAN DEPOSITS OF AFRICA

Our knowledge of the geology of central and northern Africa has advanced little beyond the point of early reconnaissance. In order to best understand the distribution and character of the rocks of the late Paleozoic, it is desirable to review first the geology of the Union of South Africa where so much good work has been done. With this as a basis it is possible to trace the various horizons toward the north with some degree of certainty.

The last authoritative statement of the geology of South Africa was given by Rodgers (1918). The Karroo system is divided by him as follows:

Stormberg series. Triassic and higher.	Feet.
Drakensberg or Volcanic beds; basaltic and andesitic lavas and tuffs of the Quathlamba and Springbok Flats areas and the Lebombo rhyolites. A time of emergence of the land over much of the Karroo following the restriction of the area during the rise of the southern ranges. Intrusion of basic rocks throughout the Union	4,000
Cave sandstones of Quathlamba, and the Bushveld sandstones of the Transvaal	800
Red beds. Sandstones and shales	1,600
Molteno beds. Sandstones, shales and conglomerates with thin coals in the Cape Province	2,00
Beaufort series. Permian and Triassic.	
Upper Beaufort (Burghersdorf beds). Shale and sandstone. A time of mountain making in the south and west of the Cape Province	3,000
Middle Beaufort beds. Sandstones and shales	500
Lower Beaufort beds. Shales and sandstones	5,000
Ecca series. Shales and sandstones; coal in Transvaal and Natal	6,200
Dwyka series. A long period of depression and deposition in the south of the Union.	
Upper shales	800
Tillite	1,400
Lower shales	1,000

The Karroo system includes the several series of freshwater and terrestrial deposits, 22,300 feet in all, between the Witteberg shales of the Cape system and the base of the Drakensberg or Volcanic beds. In only one place, in the British Southwest Protectorate (formerly German Southwest Africa) have any marine beds or marine fossils been found. The integrity of this great thickness of rocks as a system is based on the continuity of the terrestrial conditions and the elevation of the area, which was inaugurated even before the close of the deposition of the rocks of the Cape System. Extending in time from the beginning of the Permian or even the Permo-carboniferous, at least to the Rhaetic, it includes an extent of time far beyond the limits of any unit useable for the purposes of the paleogeographer. It illustrates the necessity of accepting the inception and duration of a definite set of conditions (climate, physiography, and so forth) as determining the limits of intervals or units of time in the consideration of the development of life, rather than the formal lines drawn between formations in the conventional time scales.

Before attempting to understand the minor changes in the conditions within that portion of the Karroo system, which may be selected as comparable to the Permian or Permo-carboniferous of the rest of the world, it is necessary to grasp the succession of events in the duration of the system as a whole. For this purpose we may note Rodgers's (1918) brief summary as a starting point.[1]

"The Karroo system occupies the whole of the central part of the Cape Province, almost the whole of the Orange Free State, the western side of Natal, and a large area in the southeastern Transvaal. No evidence has yet been found that marine conditions occurred in this large area of deposition during Karroo time, but in a part of the South-West Africa Protectorate two kinds of marine fossils have been found, in the lower beds of the system. In the southern Karroo the Witteberg series passes upward conformably into shales, which are taken to be the base of the Karroo system, and which in their turn pass up into a hard boulder-clay or tillite without any precise line of division. To the north of Karroo Poort the shales are wanting and there is an unconformity below the tillite. The tillite is now regarded as of glacial origin by almost all geologists, for on no other hypothesis have the peculiarities of the rock been explained. It has a matrix of mudstone or slightly laminated and sandy, often calcareous, hardened clay, containing pebbles and boulders of many varieties of rock, occurring in places to the north of the spots where they are found in the tillite, and many of them are flattened and striated after the fashion of the stones in glacial deposits of regions which are now, or have within recent times been, covered by sheets of ice. In many districts north of the Karroo the tillite rests upon striated surfaces, or characteristically shaped hummocks of rock called *roches moutonnées*, which is very strong evidence of the glacial origin of the formation. The thickness of the tillite varies from a foot or so, or it may be absent altogether, as in parts of the Transvaal, up to 1,400 feet in the southern Karroo. The general direction of movement of the ice was from the north. The tillite is followed conformably by shales in the west, south and east, but in the Transvaal there is almost certainly a break of unknown but not great extent at the top of the Dwyka series, as the lowest group of the Karroo rocks is called.

"The *Ecca series* follows the Dwyka conformably in the Cape Province and Natal. It consists of shales and sandstones, and in Natal it contains coal seams, as it also does in the Transvaal. In the south of the Cape Province the Ecca beds reach their greatest thickness—over 6,000 feet. The series decreases in thickness northwards, and in the Transvaal it is probably only a few hundred feet thick. The Ecca beds contain a flora characterized by the genera *Glossopteris* and *Gangmopteris*, which, with their fellows, are found also in the Gondwana beds of India, and in Australia and South America. In these four regions of the globe the *Glossopteris* flora occurs in beds overlying tillite like the Dwyka tillite, and it is this fact which leads to the belief that an Arctic climate prevailed over a great region in the Southern Hemisphere at the remote period when the coal measures of the Northern Hemisphere were being formed, or soon afterward. The evidence as to the age of the beds as compared with the European rocks is obtained from Australia and India, for the marine fauna on which it rests does not occur in South Africa.

"The *Beaufort series* lies unconformably on the Ecca in the Karroo region, Natal, and the southern part of the Orange Free State, and it has been definitely recognized in the southeastern Transvaal. Its most striking feature is the abundance and variety of its reptilian fossils, which are of exceptional interest because they include forms with mammalian relationships and the habit of walking with the body raised clear of the ground as proved by the structure of their legs. With the reptiles are amphibians, fish, lamellibranchs of freshwater habit, and some plants belonging to the same genera as those in the Ecca below, as well as, in the uppermost beds, a few which are found in the Molteno beds above. Sandstones, shales, and mudstones, with a small amount of limestone, chiefly in the form of nodules, make up the Beaufort beds. In the southeastern Transvaal Dr. du Toit has found that the coal-bearing beds of Volksrust are in the Beaufort series.

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[1] The history of the origin of the name, and the development of the conception of the Karroo system, is well summarized in Hatch and Costorphine's *Geology of South Africa* (1905).

"The *Stormberg series* follows the uppermost Beaufort beds conformably in the east of the Cape Province, and the neighboring part of Natal and Basutoland, and it is ushered in by shales and sandstones known as the Molteno beds, which are coal-bearing. The Molteno beds contain a flora with Triassic affinities, but none of the reptiles known from the Beaufort series has been found in them. The Molteno beds occur in the east of the Orange Free State, but they have not been found in the north of that Province nor in the Transvaal.

"The Molteno beds are succeeded in the Cape, Natal, Basutoland and the southeast of the Orange Free State by the Red beds, which are red weathering sandstones and shales containing a few dinosaurs and other reptiles, fish and perhaps the supposed mammal *Tritylodon.*

"The Cave sandstone, a rather remarkable formation of thick bedded sandstone, succeeds the Red beds conformably in the Cape, Natal, Basutoland and the Orange Free State, and it also occurs in the Transvaal where it is known as the Bushveld sandstone. It contains a few dinosaurs, a crocodile, fish and some small crustacea. The Cave sandstone makes bold outcrops along the slope of the Drakensberg in east Griqualand, Natal and Basutoland; it is very closely associated with the volcanic rocks of the *Drakensberg series* at the top of the Karroo system, and which form the precipitous portion of the Drakensberg or Quathlamba range, the Maluti Mountains, and also much of the flat country (Springbok Flats) of the Transvaal Bushveld. The lowest volcanic beds are interbedded with the Cave sandstone, and the series consists of andesitic and basaltic lavas and tuffs. A large number of the vents or necks from which outbursts took place are known, but it is probable that much of the lava came from long fissures now represented by dykes of dolerite.

"To the latest part of the Karroo period belong the *intrusions of dolerite*, which are found traversing nearly all the rocks of the Union older than the *Drakensberg series*, as well as that group. The only large tract in the Cape Province which is free from dykes and sheets of this dolerite is the Folded Belt. The dolerite sheets give rise to the long lines of cliffs capping the escarpment of the Nieuwveld and its continuations to the east and west, and both sheets and dykes form conspicuous features in the Orange Free State, Natal and the Cape Province. Only in Griqualand East have picrites and other ultrabasic differentiates of the basaltic magma been discovered, and in the Insizwa, Tonti and Ingeli masses they form important bodies of rock which may yield metallic ores of value. The acid differentiates are much more widely distributed. They are small bodies of diorite and granophyre, which rarely give rise to any conspicuous feature."

The portion of the Karroo system which carries the fauna of vertebrate animals coincident in time (or in similarity of conditions) with the Permian or the Permo-carboniferous of the Northern Hemisphere is embraced within the lower limits of the Ecca and the base of the upper Beaufort (Burghersdorf) beds. Both the Dwyka below and the Stormberg above are parts of the great development of terrestrial and freshwater conditions characteristic of the Karroo, but these series are marked by easily recognizable material and physical conditions of deposition, which permit us to trace their extent with some degree of accuracy—namely, the tillite below and the Drakensberg volcanics above. To know the geographical limits of these beds is to know the extent of the uplifted area of Africa between Witteberg and Cretaceous (Uitenhagen) time. The significance of the Ecca and Beaufort series then becomes more apparent.

The extent and distribution of the Dwyka tillite within the limits of the Union of South Africa has repeatedly been described and shown on maps.[1] Beyond the Union it has been traced less certainly through Rhodesia and Central and East Africa, and into the Southwest African Protectorate.

Permo-Carboniferous in Rhodesia and Central Africa

On the geological map of Southern Rhodesia published in 1921, the Karroo is divided into two parts only, an upper, the Basaltic lava (= the Drakensberg volcanics) and a lower of "grits, sandstones, shales, etc.," with some coal. The lower division is described by Maufe (1919) for the Zambezi Basin as an upper group of red, pebbly grits passing into red false-bedded sandstone, at least 400 feet, true top not reached. It may well have accumulated on land. A middle group of shales or mudstones alternating with nodular limestone; 700 feet. A lower group of grits, sandstones, and shales, not more than 500 feet, with two distinct horizons carrying workable seams of coal.

> "The basal beds of the Karroo system are seen resting on the ancient gneisses in several sections in the Wankie District, the most widely separated being some 60 miles apart, but never is there anything resembling a glacial conglomerate." (The Dwyka tillite has been reported as possibly present at Tuli, near Wankie.)

In neither the Highveld facies of the Karroo in Southern Rhodesia nor in the Rhodesian portion of the Limpopo Valley is there a recognizable glacial conglomerate. The fossil flora of the lower division is scanty, but so far as known it is considered to indicate Beaufort rather than Ecca age. Huene (1925[2]) says the beds can be traced from the region of Wankie, with certain breaks, through the valley of the Zambezi to the Rhodesian—Portuguese East Africa Border. He considers them of Ecca age.

In northern Rhodesia the succession of the beds in the Karroo system is, according to Reed (1921), quoting Molyneaux:

5. Volcanic series.
4. Forest Sandstone.
3. Escarpment Grits and Upper Matabele Beds.
2. Lower Matabele Beds (and Coal Series).
1. Basal beds and Boulder conglomerate.

The Basal beds "vary from an angular breccia to a well-rounded puddingstone. In the former there are fragments of gneiss and schist, but the conglomerates are largely made up of pebbles of quartz and quartzite, varying in size from that of peas to boulders 40 inches in diameter." There is no definite evidence in either striation or wear of the boulders or pebbles, or of the surface upon which they rest, of any glacial action. These beds extend some distance northeast in the valley of the Luangua (Lowanga) River and the Machinga Escarpment.

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[1] Hatch and Costorphine, 1905; Rodgers, 1905; Rodgers, 1918; Du Toit, 1918; Reed, 1921; Huene, 1925; and see maps pages 150 and 152.

Delhaye and Sluys (1917, 1920) describe a series of shaly limestones and sandstones with a conglomerate at the base in the Katanga and Kundelungu region. The conglomerate is of variable thickness, becoming thinner or thicker as the beds above vary in the same character. The conglomerate is unstratified, argillaceous-calcareous, compact and made up of pebbles, small boulders and angular fragments irregularly distributed throughout the matrix. This conglomerate is of glacial origin and is considered equivalent to, or identical with, the Dwyka tillite.

Delhaye (1919–1920) describes these beds as showing local lacustrine and torrential phases, and, in the graben of Lufira, fluvio-glacial phases. Upon the horsts of the region glacial material is preserved in depressions with intergradations between it and the superimposed material. The effect of the preglacial topography is noticeable in the distribution of the beds.

Fourmarier (1914) describes a somewhat similar series on the west side of Lake Tanganyika between the Lukuga and the Lubamba (Luama ?) Rivers. In the valley of the Lukuga, between Malonga and the Niembi River, glacial beds are exposed, similar to those of Katanga and the Kundelungu. The same beds are exposed in the near-by valley of the Kara and in the valley of Memba. This series of beds, the Lualaba formation, is composed of clay shales, sometimes reddish, clay with calcareous layers, and sandstone. In these beds occur the remains of fish, *Peltopleurus maesini* Leriche, and unidentified Semionotids and Eugnathids; Ostracods, *Caudona*; Phyllopods, *Cypris;* and plants, which indicate a lower or middle Beaufort age. These formations have been traced northward as far as Stanleyville on the Congo and eastward as far as longitude 20° East in latitude 4° South. Scattered throughout the region, patches of glacial conglomerate have been found at the base, lying upon smoothed and striated surfaces. Above the Lualaba formation is the Lubili formation of Stormberg age. (Huene, 1925^2, pages 112–116.)

Fourmarier (1914) sees in the deposits on the east side of Lake Tanganyika a portion of the beds exposed on the western side, separated by tectonic movements. These beds are displayed between Ugaga and Lake Tanganyika in the valley of the Malagarasie River and parallel to the shore of the lake between the mouth of the Malagarasie River and the Ruguvu River.

In British Central Africa, Nyassaland, Reed (1921), following Andrew and Bailey (1910) describes a layer of sandstone and conglomerate at the base of the Karroo system in the northern part of the region. The conglomerate lies on the gneiss or just above a white or red sandstone. It has large and small boulders of granite or gneiss irregularly distributed through a sandy matrix. The boulders are sub-angular or rounded; there is no direct evidence of glacial action but the equivalence of the bed to the Dwyka tillite is hardly questionable in the minds of the authors. The conglomerate is 1,300 feet thick at Mount Waller and increases to 2,000 to 3,000 toward the west, in the Luangwa region.

In their description of the Shiré district of southern Nyassaland the same authors, Andrew and Bailey (1910), give a totally different section, but at the base there are beds of large boulders, carbonaceous shales and conglomerates, associated with current bedded sandstone and pebble beds. These beds can be traced into the adjacent Portuguese territory.

In the Tanganyika Territory, formerly German East Africa, Reed selecting material from Bornhardt (1900), Krenkel (1910) and Strömer (1896), describes thick, massive sandstones as the base of the Karroo system, but no conglomerate or tillite; the upper part of the series is composed of clays, sandstones and limestones of fresh-water origin. Karroo rocks appear near the coast behind Dar-es-Salaam and Tanga. Here the beds are divided into a lower portion "composed of alternating clay-slates and coarse-grained sandstones with subordinate conglomerates, amounting in all to about 400 meters in thickness, and an upper series consisting of brownish or reddish thick-bedded, fine-grained sandstones; some of the beds yield leaves of the nature of *Glossopteris* so that they may be referred to the Lower or Middle Karroo." Similar beds can be traced in the Ruguvu River valley as far as Wiedhafen on Lake Nyassa and on the west side of the lake through the British Central Africa Protectorate.

Recently Haughton (1924) has described the skeleton of a reptile obtained by Mennel from the middle of the Karroo near Tanga. In his discussion of the age of the deposits, Haughton says—

> "The only record of fossils from the beds near Tanga is that made by W. Bornhardt who, in 1900, mentioned that in the lower part of the sequence he obtained plant-remains identified by Potonié as 'stems of *Ullmannia* (*Brachyphyllum* type)' and 'bracts of *Voltziopsis*' assigned by him to the 'Upper Gondwana' horizon. Bornhardt considered it hazardous to distinguish between the horizon of these beds and those of Nyassa and the Rufiji River, which contain *Glossopteris*, on the evidence furnished by the few plant-remains only.
>
> "*Glossopteris* is a long-lived genus; it ranges in South Africa from the Ecca Series up into the Molteno Beds. Mr. Mennel informs me that he obtained it from a horizon just above that which yielded the remains described in this paper.
>
> "If the supposed connection of *Tangasaurus* [the new form, Author] with *Youngina* be justified, then we may consider the shales which contain it as approximately the equivalent of the Middle Beaufort Beds (*Lystrosaurus* zone) of South Africa. *Youngina* is from the uppermost zone of the Lower Beaufort Beds. * * * Further evidence is necessary before any certain correlation can be made between deposits in areas so remote one from the other; but it is improbable that there is any serious error in considering the Tanga deposits as of, at least partly, Middle Beaufort age.[1]"

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[1] "Mr. Mennel has since informed me that the Karroo rocks in the locality are several thousand feet thick, and that the fossils came from the Middle or Black-shale Series of the System, as developed near Tanga, the said series being over 2,000 feet thick. The observations on the age of the beds, as determined by *Tangasaurus*, must, therefore, be taken to refer only to the strata in which the fossil occurs, and not as an expression of opinion concerning the entire System, or even of the Middle Series."

With the single exception of the evidence furnished by the reptile skeleton cited above, it is impossible to recognize the subdivisions of the Karroo in Central Africa, but it is equally evident that the basal deposits were the same as, or similar to, the Dwyka deposits of the southern part of the continent and it will be no surprise to learn of the discovery of other remains at any time in any portion of the region.[1] With the understanding that conditions prevailed in Africa, north of Rhodesia, similar to those south of it, it is possible to proceed to the more detailed description of the Ecca and Beaufort beds which carry the vertebrate land fauna.

In attempting to understand the relations and position of the Ecca and Beaufort beds it is well to understand the Paleozoic surface of Africa so far as it is revealed by the deposits of the Dwyka tillite and shales. Du Toit (1921) gives his conclusions of the general conditions—

> "Toward the close of the Carboniferous there was land north of 32° S., south of this the Witteberg quartzite and shales had shortly before been laid down under lacustrine conditions. Green and blue mud was still being laid down when the ice began to form in the north, for south of latitude 33° S. there is a conformable series from the Witteberg, through the Lower Dwyka shales to the tillite. The nature of the Upper Dwyka shale indicates marine conditions in the northwest, estuarine in the west and south, and lacustrine in the east and center of the Union of South Africa. Probably from 500 to 1,000 feet of material were removed from the surface of the elevated region in the Transvaal by the ice. The surface 'retains in a high degree the topographical relief that had been developed by subaerial erosion and finished off by the sculpture at the close of the glaciation'."

Du Toit gives the following time valuation of the African beds to which is added the faunal zones.

Dwyka tillite and Upper shales = Upper Carboniferous.	
Ecca beds = Lower Permian.	
Lower Beaufort beds = Upper Permian	*Tapinocephalus* zone. *Endothiodon* zone. *Cistecephalus* zone.
Upper Beaufort beds = Lower Triassic.	*Lystrosaurus* zone. *Procolophon* zone. *Cynognathus* zone.
Molteno and Red Beds = Upper Triassic.	
Cave Sandstone and Volcanics = Rhaetic.	

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[1] Since this statement was put into print, Dr. S. H. Haughton (Paleontology in South Africa, Presidential Address, delivered to the Geological Society of South Africa, March 15, 1926, Proceedings of the Geological Society of South Africa, 1926, pages xx–xxxiv), has reported the finding of vertebrate fossils in Northern Rhodesia—

"The Nyasaland and North-East Rhodesian forms have recently been brought to my notice through the kindness of Dr. F. Dixey, who has spent some time in examining the Karroo and later beds of his territory and I am to have the opportunity of examining a fair number of the remains. The specimens that I have seen, which are from one locality only, contain two Gorgonopsian and two *Dicynodon* skulls; fragments of other forms are also present, and we can confidently look forward to establishing the presence of a typical Beaufort fauna in that area, in which part of the beds are certainly homotaxial with the base of the *Cistecephalus* zone. The beds from which the fossils come occur (1) in a down-faulted area at Chiweta, south-east of Mount Waller, in North Nyasa; (2) in what is probably a down-faulted area on the Rukusazi River, a tributary of the Luangwa River, northwest of Fort Jameson, in North-East Rhodesia. Chiefly purplish and mauve mudstones, sandstones, grits and conglomerates with calcareous lenticles and concretions, they contain no invertebrate remains, and may be looked upon as terrestrial and paludal deposits somewhat similar in origin to the South African Beaufort Beds. It is important to note that they occur in down-faulted areas; and the further northward extension of this fauna in Africa will probably only be proved by the discovery of beds similarly preserved by down-faulting. The fossils from Tanga, which was called *Tangasaurus*, is an aquatic form, and the beds in which it occurred may have been laid down along the shores of that land on which lived the typical African Permian and Triassic reptiles."

In the Southwest African Protectorate, formerly German Southwest Africa, the Karroo appears in the south and in outliers as far north as the Gobabis District; it is considered possible that the Kaoka beds of the Kaokaveldt may be also Karroo. The beds reveal that glacial conditions prevailed at first and were followed by terrestrial conditions. At Nanabis on the Lion (Xamob) River there is typical tillite on a pavement of glaciated older rocks associated with conglomerate, calcareous sandstone and shale, all of glaciofluvatile origin. At a higher horizon there is a boulder-bearing mudstone formed apparently from material deposited from floating ice and embedded in a sandy argillaceous matrix; this phase passes imperceptibly into shales carrying *Eurydesma globosum* and *Conularia* equivalent to the Australian Permo-carboniferous forms.

The glacial beds are 900 feet thick at Keetmanshoop, but are variable in thickness at other places. Occasionally there are limestone layers intercalated in beds of tillite. The *Eurydesma* shales are succeeded by a shale with sandstone, and near the top of the series there is considerable gypsum. The upper shales and mudstones appear to be equivalent to the White Band of the Ecca.

East of Gibeon the Dwyka is covered by a soft, grayish, micaceous sandstone with occasional dark shales, 560 feet in minimum thickness; similar beds occur in the Gobabis District, they carry *Glossopteris*, *Cordaites* and *Calamites*, but no coal seams were formed. Wagner has tentatively referred these beds to the Ecca horizon. The Ecca horizon is overlain north of Gibeon, in the Gobabis District and in the south of the Rehobath District, by horizontal sheets of basalt with interbedded sediments; these are referred to the Stormberg.

In the Kaoka District there are horizontally bedded sandstones and shales with occasional beds of conglomerate, overlain by amygdaloidal melaphyr and augite porphyrite. This, Kaoka, series lies unconformably upon the Otavi Dolomite. The volcanics are probably Stormberg in age and correspond to the flows of the Drakensberg and the Zambezi region.

It is apparent that though no certain evidence of glacial deposits has been discovered north of the Transvaal border, the lower beds of the Karroo system are such as show, at least, the effect of a disappearing ice sheet as far north as latitude 3° N. Lacking, as we do, any definite information concerning the movement of the ice in the northern part of the area occupied by the Karroo system, it is, perhaps, premature to venture much in the way of an attempt to describe the pre-Dwyka topography, but the facts cited in the preceding sentence indicate something of the conditions.

On the other hand, the movements of the ice south of the Transvaal border are fairly well understood and these point with considerable definiteness to the center, or centers, of accumulation. Du Toit (1921) identifies four distinct centers of distribution of the ice. One in an area now sunken beneath the waters of the Indian Ocean from which the ice moved generally southeast over Natal; one in an unlocated spot north of Namaland from which the ice moved in a direction a little west of south into the Cape Province; one in the north part of the Transvaal, near the Zoutspanberg and a little south of these mountains, from which the ice radiated fan-wise over that portion of the Union of South Africa to the south of the center, over Griqualand West and the southern half of the Southwestern Protectorate. The fourth center was a subsidiary one in Griqualand West. It is reasonable to suppose that the third mentioned area was the main center of dispersal and we may expect that evidence will be found in Central Africa of ice movement to the north, from this center.

The basaltic flows and related volcanics occur as far north as 30 miles north of the Zambezi in Northern Rhodesia; their extent to the east is cut off by a fault, according to Lamplugh. The center, or area, of main discharge of the lava has not been located but the extent is enormous, from north of the Zambezi to as far south as the Nieuwveldt in the Cape Province and from the Kalahari desert in the west to the Drakensberg in the east. The association of the great mass of extruded material with the enormous accumulation of sediments constituting the Karroo system is most striking; the flows occurred in the region of maximum accumulation, covering or penetrating the beds; in the peripheral regions where the load of sediment is less the flows are correspondingly less in amount or absent.

The ice movement so far as traced, the distribution of the Dwyka tillite or its equivalent, and the distribution of the basaltic lavas, all indicate in a general way the major features of the south half of the African continent during the time of the deposition of the Karroo sediments. From the dominant area in the northern part of the Transvaal the sediments were distributed in a radial manner in all directions. The proximity of the granite, and associated older crystallines, to the surface in Rhodesia[1] show how effectively the land has been denuded of surficial material, if any such existed.

It is possible, then, to recognize a distinction or separation purely physiographic in character, between the region north of the dominant physiographic area and the region to the south, and the nature of the sedimentary series in the two regions, so far as they may be analyzed from what is known of them, tend to emphasize the distinction.

Turning now to an attempt to isolate a reasonable interval of time and succession of conditions which may be compared with the Permian and Permo-carboniferous of the Northern Hemisphere, we find that we must confine ourselves (simply because of the available information) to the area south of the dominant physiographic area in northern Transvaal. Here we find that the Ecca and Lower Beaufort Beds are generally regarded as

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[1] "If for a moment we include the intrusive igneous rocks, it is actually the case in Southern Rhodesia that one might travel from end to end, from Plumtree in the west to Umtali in the east, or again from the Limpopo River to the Zambezi River, on the one formation, which is also the oldest known." (Maufe, 1919).

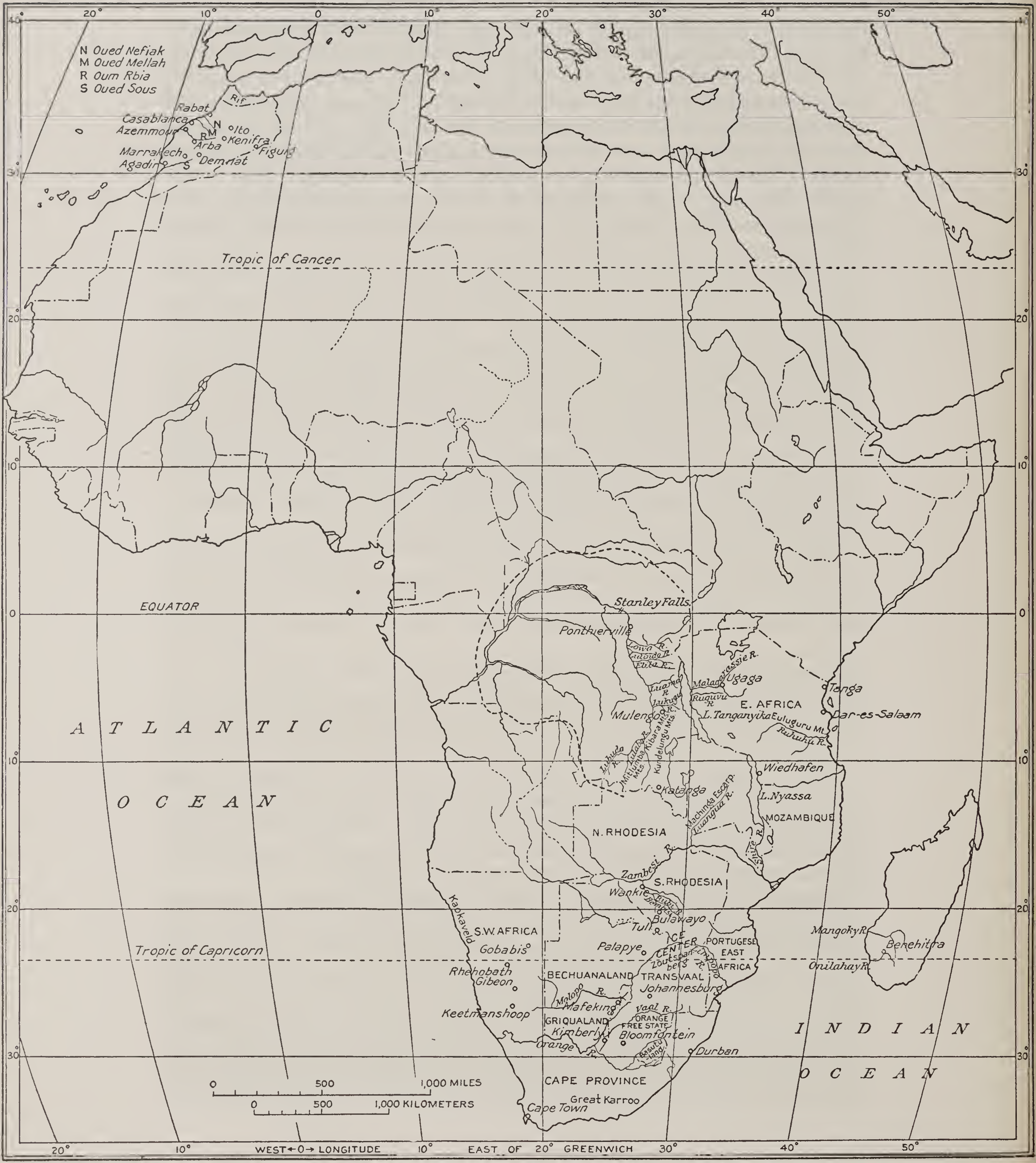

FIG. 19.—Sketch map of Africa showing localities mentioned.

approximately equivalent to the Permian and Permo-carboniferous, and the Middle (when recognized) and Upper (Burghersdorf) Beaufort beds to the Permo-triassic. Because the beds are entirely terrestrial (except the little-known marine beds of the Southwestern Protectorate) there is the same difficulty in drawing formal stratigraphic lines as there is in the European deposits, but there is one great distinction to be made between the two in regard to the development of life. As the author has repeatedly shown, there is a very sharp break in the record of life in North America between the uppermost Permian or Permo-carboniferous and the Triassic; the interval of time is represented by several hundred feet of barren beds. The same thing holds true to only a lesser degree in Europe. In South Africa, wherever the section is preserved, there is a regular, graduated change from one to the other, and none of the beds are devoid of fossils; the record of life, if not complete, is at least unbroken.

The Permian, Permo-carboniferous and Permo-triassic beds of South Africa have been repeatedly described and discussed by Broom (1907), Watson (1914), du Toit (1918, 1921), Haughton (1919), and Huene (1925²). The extent and distribution of the Karroo system and the demarcation of the various zones of vertebrate fossils are shown on the accompanying map arranged from those of Watson and Huene. On this map only the localities mentioned have been plotted. Reference to any map of South Africa will locate them with regard to other places and natural features.

Drawn very largely from du Toit's excellent description (1918), the following summary will show the main characters and distribution of the beds on the south side of the dominant area in the northern part of the Transvaal.

The Dwyka beds have been extended by the Cape Province geologists to include "several hundred feet of argillaceous strata" called the Upper Dwyka shales. In Natal the Dwyka has been considered to terminate at the upper edge of the tillite; in the Cape Province and the Southwestern Protectorate there are transitional beds with erratics between the tillite and the Ecca shales. A conventional line has been drawn "at the top of a zone of carbonaceous but white-weathering shale—the 'White Band'—this ending with a bed of chert in the west and south." This distinctive relation and the conspicuous 'White Band' have been observed from near Kimberly right around the western Karroo to Grahamstown, and have been followed in to the Southwestern Protectorate. In the eastern part of the Cape Province, between Port St. Johns and the Natal border the White Band is almost gone; it is represented by a small development of "coaly-looking shale between the tillite and what has been regarded as the true (blue) Ecca; even this carbonaceous zone fails in Natal." Du Toit regards it as most probable that there is a true stratigraphic break between the tillite and the Ecca in the southeastern part of the Karroo Basin. In describing the Ecca beds one can do no better than quote farther from Du Toit's paper.

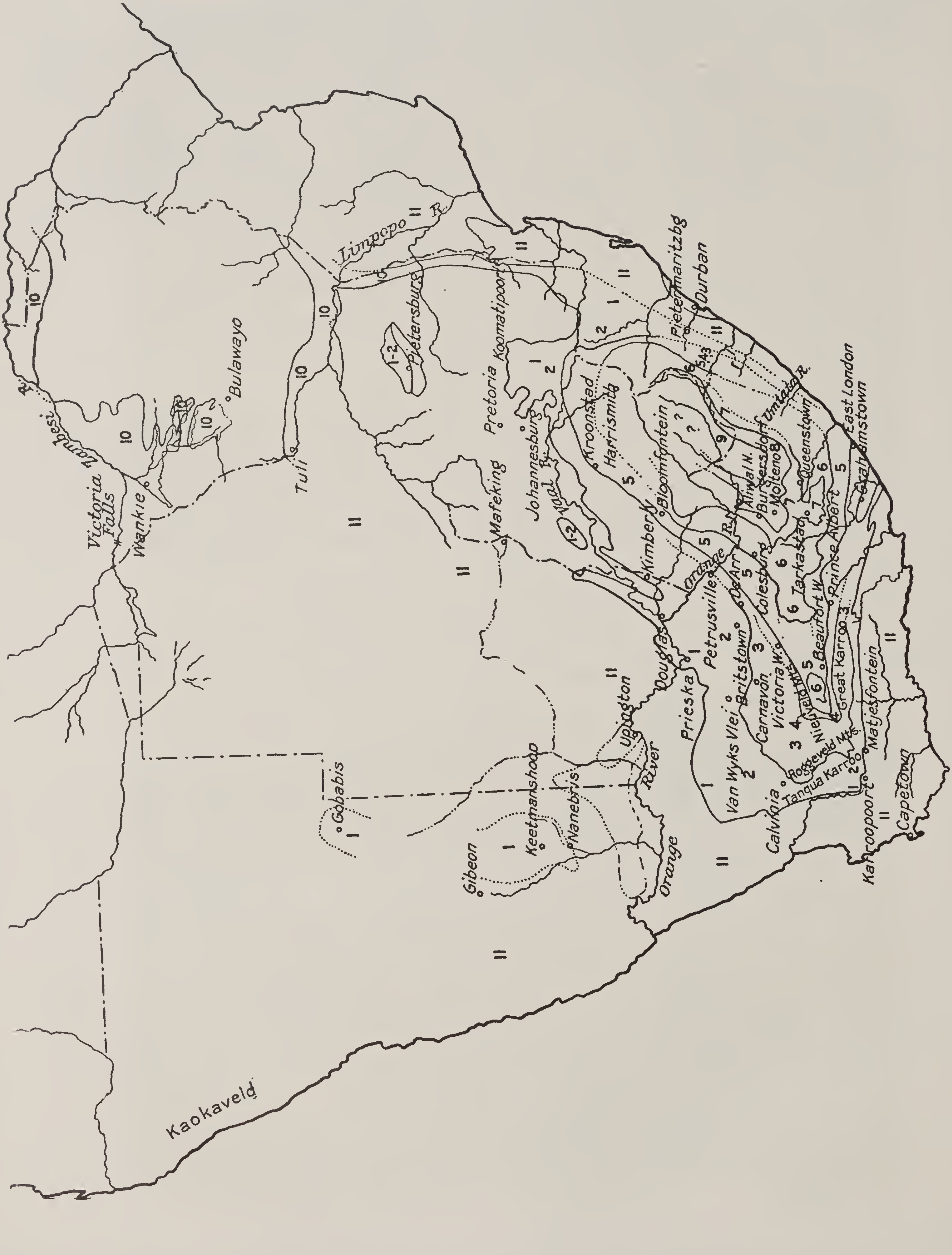

Fig. 20.—Sketch map of South Africa showing localities mentioned and the extent of the fossil zones.

11 Pre- and post- Karroo. 10 Karroo, Perm. and Triassic. 9 Cave sandstones and Red Beds. 8 Molteno. 7 Cynognathus zone. 6 Lystrosaurus-Procolophon zones. 5 Cistecephalus zone. 4 Endothiodon zone. 3 Tapinocephalus zone. 2 Ecca. 1 Dwyka.

"Along the entire northern margin of the 'basin' from Petrusville past Van Wyk's Vlei to Calvinia, and then round to the Tanqua Karroo in the west, this group consists of unfossiliferous blue or greenish shales a full 2,000 feet in thickness. When followed southward toward Karroo Poort, sandstones make their appearance, more particularly a little above the middle group; green mudstone replaces much of the blue shale, while purplish varieties of the former are not uncommon; *Gangmopteris*, *Glossopteris* and *Phyllotheca* can now be obtained, though sparingly. At the same time the thickness increases rapidly; about 3,000 feet in the Klein Roggeveld, and still more so along the southern margin of the Karroo, where, to the south of Aberdeen, Dr. Rogers has measured over 6,000 feet of this arenaceous phase, the facies being almost identical with that of the succeeding Beaufort beds of this quarter, for which reason the boundary line between the two series is not at all well marked hereabouts. It is particularly interesting to find making their appearance in this phasal development of the Ecca, the forerunners of the host of quadrupeds characteristic of the Lower Beaufort beds of the area between the Witteberg and Nieuweveld.

"The principal source of the sediments in the stretch between Matjesfontein and Grahamstown certainly lay well to the south, as we may infer from the fact that the sandstones are invariably medium grained, while grits and conglomerate are absent. Whereas in the Ecca Pass at Grahamstown over 4,000 feet of strata are represented in which sandstones, including hard dark-greenish varieties, play an important rôle. Upon crossing the gap to Pondoland the Ecca series is only 2,500 feet in thickness, almost wholly argillaceous and comparable in almost every respect with the corresponding beds of the Northern Karroo. At the Natal border there sets in, however, a change in facies, the non-recognition of which has led to much misconception regarding the stratigraphy of that Province. An arenaceous group makes its appearance about three-fifths up in the series, being still under and overlain by soft blue shales, and this separable division, when followed northwards becomes strongly developed and of great economic importance, inasmuch as it constitutes the so-called 'Coal Measures' both of Natal and the Southern Transvaal."

The Ecca beds are regarded as existing in three horizons, or phases. The Lower Ecca Beds are now known to be the equivalent of the Pietermaritzburg Shales of the earlier descriptions. Du Toit traces the course of these shales in some detail, through Natal to its northern portion, Paulpietersburg; beyond the Pongola River these shales are only slightly developed and at Ermelo they have entirely disappeared and the Middle Ecca Beds rest directly upon the older rocks. The disappearance of the Lower Ecca beds is proof to du Toit of the stratigraphic break between the tillite and the Ecca Beds in Natal.

The Middle Ecca beds are the "Coal Measures" of the Transvaal and Natal usage. Du Toit points out that the coal is not confined to this horizon but is found in certain places in the Beaufort beds; also he points out the unfortunate character of the usage as seemingly to imply a Carboniferous age of the beds when, in truth, they "correspond with a high degree of probability with the extreme base of the Permian of Europe, *e. g.*, with the lowest portion of the 'Rothliegende'". These beds have a basin-like character in Natal, increasing toward the north and then thinning again toward the west and in the Transvaal. The material changes from dominantly arenaceous in the south to a series of thick grey flagstones and "soft, very micaceous sandy shales with subordinate thin whitish fine-grained sandstone; true laminated blue or black shale is, however, very rare." Characteristic of these beds are the abundant nodules, lenticular masses, and even layers, of calcareous sandstone or impure limestone. In the upper portion, between Ladysmith and Dundee, oval ferruginous concretions are rather abundant in a thin zone of dark shales; these carry fish remains. The beds continue in the Transvaal to Vereeniging and thence southwest to Kroonstadt.

The Upper Ecca Shales are remarkable for their uniformity in thickness and lithological character throughout Natal. "Composed throughout of soft blue shales like those of the lower Ecca, great interest attaches to them because of the frequent presence of hard grayish concretionary nodules, lenticles or thin impersistent layers fairly rich in phosphate of lime." This zone has been recognized at Kroonstadt in the Orange Free State, and in the Cape Province it has been traced from Petrusville westward past Britstown, where it is a shale, as is the whole of the Ecca series.

THE BEAUFORT SERIES

> "Rough limits may be set by drawing a line westward from East London past Prince Albert Road to the Klein Roggeveld, northward along the Roggeveld escarpment almost to Calvinia, eastward past Carnarvon to De Aar, thence northeastward past Kroonstadt to Volksrust, then south through Natal, * * * and through Pondoland via Fort Donald and Old Buntingville to the Umtata River mouth.
>
> "East of the main boundary in Natal there are a number of conspicuous outliers *e. g.*, the Biggarsberg, Indumeni, Umkolumbi, and very probably the summits of Pakadi Peak, Mount Allard and the Umsinga Mountain, while, as will be shown later, the series must reappear in the down-warped Somkele-Komatipoort belt."

The Beaufort beds have been split into six zones based upon the contained vertebrate fossils; these are the—

Cynognathus
Procolophon
Lystrosauurs Zones
Cistecephalus
Endothiodon
Tapinocephalus (Pareiasaurus)

Du Toit finds that while stratigraphic work upholds this grouping in the main, the limits of the zones are not exactly determinable upon the character of the beds and that only one, the *Lystrosaurus* zone, is mappable as a distinct unit. Upon evidence other than that of the fossils the beds are divisible into three horizons; of these the middle is "relatively thin but, nevertheless, persistent."

LOWER BEAUFORT BEDS

Except in the Southern Karroo this group carries thick layers of fine to medium grained yellow felspathic sandstone alternating with thick bodies of blue, green or occasionally red or purple mudstones and shales, sometimes with calcareous nodules. In Natal, these brilliantly colored strata are absent, being best developed over the Western Karroo, where also the thinner sandstones are fine grained, dark green in color, particularly hard and much jointed. This zone is probably only a few thousand feet thick in the Northern Karroo (Sutherland-Hanover), but in the Southern it is enormously developed—perhaps as much as 7,000 or 8,000 feet; significantly, too, it is here prolific in reptilian remains. In the central and eastern Transkei its value may be taken as from 4,500 to 5,000 feet, falling off in a northwesterly direction, *e. g.*, in Mount Currie 2,5000, Bulwer-Deepdale 1,900, Van Reenen's Pass 1,000, Newcastle 1,200, and Inkwele 1,100, which is the most northerly point in the main basin where measurements can be made.

"At the same time, a distinct but very gradual lithological change becomes apparent; the cream or dark drab-colored fine-grained sandstones get whiter and coarser in grain and better defined, until in northern Natal they are thick felspathic grits with little quartz-pebbles and occasional inclusions of granite, greisen, quartzite, etc., practically indistinguishable from those of the Middle Ecca. Concurrently the softer strata, normally blue and green and rather of the mudstone type, become differentiated into thin sandstones and dark green, blue or grey fairly well-laminated shales. True very fine-grained carbonaceous shales carrying plant remains, small crustacea and fish scales now make their appearance in layers that, although thin, are persistent over wide areas and may be accompanied by thin impure coals. These last are rarely more than a few inches thick, for example, Glandisrock, Inhulanzi, about Mooi River, Willow Grove, Estcourt and Frere, and at Zand Spruit, near Bergville, but between Volksrust and Wakkerstroom, at the very base of the group, compound seams are found, including as much as two feet of coal. * * *

"In the Orange Free State the variations must be of the same type as in Natal, the fine-grained sandstones of the Luckoff-Bloemfontein region giving place to the coarse grits of Kroonstadt and the northeastern part of the Province; beds of this zone, as a matter of fact, extend northeastward in a tongue up to the Molen River as far as Van Reenen's Pass."

The Middle Beaufort Beds are transitional between the Lower and the Upper, and the horizon is everywhere thin.

"Its base can be distinguished through the general red, purple and green tints of the softer strata, though except in the north this line is not strongly marked; its superior limit, however, has been drawn at the top of a very massive yellow sandstone that generally makes a conspicuous feature. The anomodont reptile *Lystrosaurus* has so frequently been found in the brightly colored mudstones from Naauwpoort, in the Cape, round to Harrismith, by way both of Natal and the Orange Free State, as to constitute itself the zone fossil; as far as is yet known this genus does not occur above the thick sandstone aforesaid. The maroon-colored mudstones at Biejspoort Station not unlikely belong to this group and, if so, constitute its westernmost extension along the main watershed of the Great Karroo. There is no doubt, however, concerning the horizon of the sandstone-capped plateaux between Naauwpoort and Middleburg (Cape), while the two northeasternmost outliers of this stratum are respectively Lang Kranz, southwest of Volksrust (where the three Provinces come together) and Ntabankulu, north of Utrecht. The zone produces terraced country between Memel and the Molen River and between Harrismith and Bethlehem, otherwise the distribution through the Orange Free State is unknown. In the Transkei and Natal long stretches have been mapped, the breadth of the outcrop being always narrow; the sandstone composes the crest of the Berg from Botha's Pass to Van

Reenen's, while outliers cap several conspicuous peaks, *e. g.*, Inkwelo, Inhluzani, and Impendhle in Natal, and Insikeni and Umgano in East Griqualand.

"North of Rosmead the thickness probably well exceeds 1,000 feet; in the Transkei it is about 800, and from Bulwer northwards it is uniformly about 500. The change in facies, as would be expected, is slight; the softer strata, normally including thin sandstone beds, become thinner and somewhat argillaceous, but the main sandstone becomes coarser in grain and more massive."

Upper Beaufort or Burghersdorf Beds

"This subdivision has prominent beds of yellow or buff weathering felspathic sandstones, invariably fine or medium grained, alternating with blue, red, purple or green mudstones and shales, like those of the underlying groups. The softer maroon-colored beds characteristically show splotches or streaky layers of pale greenish-blue tint; red calcareous concretions are common.

"The maximum development is once again in the southwest, *e. g.*, Burghersdorf, Tarat and Queenstown, while through the Transkei and Natal the outcrop becomes progressively narrower owing to the thinning of the zone in a northeasterly direction, *e. g.*, central Transkei, 2,000 feet; Mount Currie, 1,800 feet; Ipolela-Impendhle, 1,004 to 1,200 feet; Hlatikulu 1,000 feet; Bezuidensout's Pass and Harrismith 600 feet; Verkijkerskop 300 feet; Tafelkop 200 feet; and Potberg 150 feet—the last two being situated immediately to the southwest of Memel. Except that the zone is thin between Thabanchu and Marseilles, the variation to the west of Basutuland is unknown. The diminution in a northeasterly direction is in part connected with the unconformable overlap of the Red Beds in that quarter. * * * Curiously enough the zone shows no corresponding lithological variation worth noting."

In discussing the life of the Karroo Beds, Haughton (1919) makes the following remarks:

"The surprising thing about the Ecca Series is its barrenness. In the north and west the formation consists of at least 2,000 feet of blue and green shales, the thickness increasing southward until a maximum of 6,000 feet occurs to the south of Aberdeen, where in addition to the shales there are thick sandstones and mudstones. Du Toit has shown that in Natal the series is a 'three-phase' one—Upper and Lower Shales separated by Middle Sandstones. Toward the north the Lower Shales are missing, as are the Upper Dwyka Shales, and the Coal Measure Sandstones directly overlap onto the Glacial Conglomerate or older rocks. The Karroo area in Ecca times has therefore been imagined as an almost landlocked area, probably open to the sea on the west, covered by shallow water, which was continually receiving enormous masses of sandy and muddy material from lands to the north, east, and south. The superior thickness and arenaceous nature of the southern phase compared with the thickness and argillaceous nature of the northwestern phase have been used as evidence in favor of this conception of Ecca geography. The bones found in Prince Albert were certainly transported to their places; but they carry no evidence of intense rolling and may not have come from afar. The clay-pellet conglomerate in which *Archaeosuchus* is embedded has in all probability been formed *in situ* by the rolling of underlying mud by a current. Considerable interest attaches to the footprints from Zak River. They indicate shallow water or shoal conditions, and lead to the supposition that the whole of the Karroo area must have been, in Ecca times, a region of vast mud flats at or near sea-level, onto which, in view of the low relief of the country, nothing but the finest silt was carried, save in the lowest portions adjacent to the northern land. Frequent ripple-marking of shales confirms this."

Watson (1913) in his discussion says of the Beaufort Beds as a whole:

"The whole series has a thickness of roughly 9,000 feet, the greater bulk of which is composed of mudstones. These rocks are usually of very fine grain and, as a rule, are not bedded; they often show banding, a difference of colour and texture, but are very seldom bedded; that is to say, it is usually impossible to expose a flat level surface of them, for they break into small cubical pieces so as to leave a quiet irregular face. They are broken up by sandstones, usually impersistent, and usually also of very fine grain. In the middle of the series, on the Great Winterberg, and also, so Dr. Broom informs me, on the Compass Berg, is a much more powerful development of sandstones of a massive kind and generally coarser grain.

"The color of the lower beds is usually dark grey or olive, the sandstones being of the same color on fresh fractures, although they weather brown. The middle of the series, with the thick sandstone mentioned above, is of a lighter tone, the sandstone being yellow and the shale light green or red. The top of the series is almost entirely red in colour, with some green and yellow beds of sandstone and occasionally purplish layers.

"Many unusual rock types occur. In the upper beds the sandstones are almost invariably cornstones; that is to say, the angular sandgrains are scattered irregularly in an ophitic manner through large calcite crystals, whose cleavage remains quite apparent. The type is exactly similar to that found in the Upper Old Red Sandstone of Forfarshire.

"Another type of the Cornstone, resembling some of those in the Lower Old Red of Herfordshire, in which the crystals are not apparent and the included material is very fine mud, if any is present at all, is also common in the upper beds, where it often surrounds bones.

"In certain places masses of mudstone, usually of a purplish colour, are found, which are penetrated by irregular strings of calcite running in the main more or less vertically, but often branching and having the appearance of the roots of a plant. In one case (Donnybrook, Upper Zwoort Kei, District Queenstown) I found in association with such a rock reniform masses of clear crystalline calcite, about 4 cm. in diameter, in a deep red mudstone.

"In the lower beds the mudstones contain immense numbers of nodules of irregular shapes, which are very hard and apparently only slightly calcareous; they sometimes surround bones, and their intractable nature adds much to the difficulty of working on South African fossil reptiles.

"Clay pellet conglomerates are common, particularly in the upper beds, where they often contain small fragments of bone. Pebbles are almost entirely absent; except for two or three found by Dr. Broom, none are known from this thick and widely spread system. * * *

"The problem of the mode of origin of the rocks which present the remarkable features detailed above is a difficult one. Bain in his first paper recognized that they were not of marine origin because of the entire absence of all salt-water shells. He considered them of lacustrine origin, an explanation which seems to have satisfied most observers to the present day. Stow, however, seems to have been doubtful about it.

"It is interesting to compare the features of the Beaufort Beds recorded above with those of the Tertiary deposits of the Great Plains of North America, also formerly considered as lacustrine. With suitable modifications the following quotation from Leidy relating to them will apply to the Beaufort Series. 'Whilst the geological formation makes it appear that the fossils were deposited in ancient lakes, or in estuaries or streams connected with the latter, it is strange that they exhibit no traces of fishes or of aquatic molluscs intermingled with the multitude of relics of terrestrial animals. * * * Even mammals of decidedly aquatic habitat are absent; with the exception of the shore-living rhinoceros and the beaver, no amphibious mammals have been discovered. Whilst the fossil bones are in perfect preservation, their original sharpness of outline without the slightest trace of erosion indicates quiet water with soft muddy bottom.' The work of Matthew, Fraas, and Hatcher has shown conclusively that these deposits are not of lacustrine origin, but were laid down on vast plains as flood-plain and river channel deposits modified by wind action. Matthew has shown that the river-channel sandstones contain the remains of forest and river-living animals, whilst the fine clays enclose the skeletons of plain-living types.

"The whole of the lines of evidence used by these geologists applies *mutatis mutandis* to the Beaufort Series. The vast majority of the Karroo reptiles are dry-land types. *Dicynodon*, which occurs throughout the entire series, is a large and very diverse genus into which the Scotch *Gordonia* could be put; some of the South African types are, in fact very similar to that form. *Gordonia* occurs in a sandstone, all the grains of which are large and rounded, and in which the pebbles, occurring in thin impersistent bands, are all of characteristically wind-cut shapes; in fact, there is every reason to suppose that *Gordonia* is a desert animal. There can, therefore, be no doubt that *Dicynodon* is also a dry-land type.

"Besides the Pelecypods and fishes the only types that we have any reason at all for regarding as aquatic are *Lystrosaurus*, and the Stegocephalia—the presence of lateral line sense organs on the skulls of which show that they must have been to some extent water living.

"I have pointed out above that the remains of fishes are apparently confined to the stratified shales and sandstones, and that the Stegocephalia, which are never common, are proportionately less rare in the sandstones.

"Of the only two *Lystrosaurus* localities I visited, one was in very obviously bedded sandstones, the other in sandstone and not so well bedded shales. * * *

"We have therefore in the stratified and unstratified beds something of the same kind of difference of fauna that there is between Matthew's river-channel and flood-plain types of deposits."

Dr. Watson records the fact that the skeletons are most commonly found complete and in a perfect natural position without any post mortem disturbance of the bones.

"Had the Beaufort Beds been deposited in a lake, the places where these skeletons were found would have been more than a hundred miles from its shore; is it conceivable that they could have been transported this distance and then deposited in the exact position in which they died?

"The extreme fineness of all the sediments implies that the agent which deposited them was incapable of moving anything larger than a small sand grain; is it conceivable that it could have carried the huge bones of *Pareiasaurus* and the Deinocephalia?

"Had the Beaufort Beds been deposited in a huge lake, we should expect to find very finely bedded shales full of plants, shells, and fishes, and containing occasionally scattered bones; instead we find great masses of unstratified rocks with many sets of associated bones, and only very rarely, and then in stratified beds, fishes and plants.

"The whole series of facts adduced above appear to be quite inexplicable on any lake theory of their origin, but receive a ready explanation if we suppose the deposits to have been laid down on land largely by wind action, though also to some extent in small lakes or ponds, and perhaps wide and impersistent rivers. I think it not improbable that the curious cornstones may have something to do with an efflorescence of calcareous matter similar to that which is now common in the Karroo.

"It may perhaps be interesting to compare the great unbedded masses of mudstone

> with loess, which they resemble in the fact that their constituent particles are, in the sections I have at present examined, always angular, a common feature in fine wind-born material."

Du Toit (1921) gives a summary picture not unlike that of Watson:

> "With the melting of the ice-sheets the borders of the lands were submerged and a series of strata laid down, varying in places from marine through estuarine and lacustrine to continental types over considerable portions of the area and to a thickness of many thousands of feet.
>
> "During this lengthy period the geographical and climatic conditions changed repeatedly over the entire continent, as would be expected. In South Africa land prevailed in the north of the Union, and the muds and sands washed down therefrom collected in an everdeepening trough in the south. This latter probably formed an immense extent of flats, now flooded, now dried up or dotted with lakes and pans; entombed in the silts thus laid down over them are the fossil remains of animals and plant life."

From the descriptions quoted above, and from similar descriptions by Abel (1922) and Huene (1925[2]) it is possible to form a very fair picture of the conditions of life during the late Paleozoic time in South Africa. The site of the Karroo sedimentation was essentially a large receiving basin between the elevated lands of northern Transvaal and Southern Rhodesia, and the elevated portion of the southern part of the Cape Province. This basin, or area, was temporarily open to the sea on the western side as is evidenced by the marine fossils found in the Southwestern Protectorate, but the marine connection was soon closed and through all the rest of Karroo time it was an area of aggradation receiving terrestrial sediments derived from more or less distant highlands. Under varying climatic conditions the surface of the ground was essentially level and uninterrupted by large physiographic features such as great and sudden changes in height, or great bodies of water, or water courses.

The problem of evolution of the life is essentially different from that of the earlier part of the Rothliegende in Europe, where prominent barriers prevented free intermigration of the faunas of the isolated basins. It is necessary to look to the varying climatic conditions, to conditions outside the area of sedimentation, or to minor factors less easy of evaluation, to determine the origin of the successive series of dominant reptiles so clearly indicated in the several zones.

After the retreat of the ice in Ecca times, the climate was probably cool and damp, a condition which extended even to the surface of the high bordering lands, as is shown by the color of the beds which carry only the lower oxides of iron, staining them green and blue. It is not improbable that the ice still lingered as a waning sheet upon the surface of northern Transvaal and Southern Rhodesia for, at least, a part of Ecca time; certainly the water table was near the surface. The inhospitable nature of the region is shown by the lack of fossils.

In the southern portion of the area, near Karroopoort and along the southern line of the Karroo, sandstones derived from the southern highlands mixed with purplish slates and green mudstones, all rapidly increasing in thickness toward the south, indicate the proximity of the southern degrading area, while the nature of the material indicates more normal climatic conditions than in the north. The presence of the *Glossopteris* flora and the first of the true Karroo reptiles, *Eccasaurus priscus* Broom (a Dinocephalian) and *Archeosuchsu cairncrossi* Broom (of doubtful position, either a Dinocephalian or a Therocephalian, both from near Prince Albert), show that the southern highlands were probably occupied by an abundant fauna and flora. A small collection of plants of the *Glossopteris* flora from near Vereeninging suggests that the hardy plants were closely following the retreating ice to the north, and the presence of the "Coal Measures" of Natal and southern Transvaal show that in places, at least, the flora was abundant by Middle Ecca time.

The presence of considerable phosphate of calcium in the Upper Ecca beds, occurring as nodules and as "impersistent layers" devoid of fossils, may be significant as indicating a stagnant condition of the waters, if Blackwelder's arguments are accepted as in part applicable to non-marine waters. (Blackwelder, 1916.)

As noted on page 154 of this publication, Du Toit calls attention to the fact that the Beaufort beds are divisible into only three parts—"on other evidence than that of fossils"—although six life zones are clearly marked by the vertebrate fossils. All descriptions insist upon the increase in thickness toward the south and the increase in the amount of sand and felspathic material toward the north. The fine-grained mudstones and shales are dominantly dark green and blue, but with an increasing amount of purple and red toward the top of the series. All writers speak of the hard and splintery character of the slates and mudstones, but in the author's opinion this is a purely secondary character and not to be taken into consideration in the interpretation of the conditions during the time of the deposition of the beds. While examining the Beaufort beds the author was constantly struck by the similarity in the appearance of the material to certain of the widely distributed Permo-carboniferous beds in the southwestern part of the United States; repeatedly he placed small fragments of the shale in his mouth, expecting it to dissolve into an impalpable mud as does the Texas clay of the Red Beds, but this never happened. It was only as the author became aware of the vast extent and enormous quantity of the intruded basalts that he came to the conclusion that the clays had been baked into their present condition long after the time of their deposition.[1] Such a process was actually observed in several places in the *Lystrosaurus* zone where the course of a dike could be traced through the clays.

It is apparent that the gradual filling of the basin, permitting underground drainage of the upper layers, and the gradual decrease of the excessive waters derived from the melting ice-cap, which had disappeared by Beaufort time, had permitted a change in the surface of the Karroo sedimentation area, from a water-sodden semi-tundra to a well-watered lowland with a much more salubrious climate. The increase in the amount of ferric oxide formed, revealed in the increasing amount of red color in the shales and sandstones, tells of warm uplands with periodic changes in the amount of humidity.

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[1] It is very possible that the hardening process was rather one of combined baking and infiltration, than of baking alone.

This land of rivers with broad flood-plains and extensive, or transient lakes, became the home of an abundant and varied terrestrial and semi-terrestrial vertebrate fauna. In or near the water bodies lived the great Pareiasaurian Cotylosaurs, some smaller reptiles, and the great Stegocephalians; upon the highlands lived the Dinocephalians and the carnivorous Therocephalians. Attention has been repeatedly drawn to the fact that the skeletons of the great Pareiasaurians are almost invariably found in the dark shales and mudstones, the bones in natural association and the body lying on the ventral surface. This has been accepted as evidence that the animals died in their natural habitat, a swamp or a great flood plain. On the other hand the bones of the Dinocephalians and the Therocephalians are found isolated, or as partial skeletons, indicating that there has been some transportation, not necessarily for a great distance as the bones are not decayed or water worn.

The food supply of the great Pareiasaurians remains a puzzle. Few plant remains have been found and these are large stems, near Laingsburg, associated with pebbles derived from a siliceous shale which occurs north of Mafeking. Such stems were evidently floated in from a considerable distance by some river current and the sparse pebbles were possibly tangled in the roots of the floating stems (Huene, 1925[2]).

Huene tells of finding a colony of fresh-water lamellibranchs, *cf. Paleomutela*, associated with the skeleton of a Dinocephalian. Specimens of a fish, *Elonicthys* sp. Broom, are also reported from these beds. None of these things could have been used by the great Pareiasaurians as food, for their weak teeth with delicate sharp cusps were not fitted for the mastication of such material. Near Abramskraal the author, accompanied by Doctor Haughton, noted the presence of large masses of calcareous and siliceous material, sometimes 50 feet long by 20 or more wide and at least 5 feet deep, lying in the dark-green mudstones; the weathered surfaces of these masses presented an appearance much like that of weathered masses of fossil algae or Stromotopora. It is very possible that floating masses of algae or similar soft material furnished the food of the Pareiasaurians. Such an explanation would be no more strange than the very similar one offered for the food supply of the Sauropodous Dinosaurs of the Jurassic.

One thing that struck the author most forcibly in his examination of the beds of the *Tapinocephalus* zone was the singular monotony and homogeneity of the environment over large areas, in contrast with the varied environment of the Permian and Permo-carboniferous of Europe and the United States. In the latter places the vertebrate fossils are found in comparatively large quantities in restricted areas where attractive surroundings caused the concentration of the fauna, or peculiarities of transportation caused the assemblage of cadavers and the preservation of the skeletons. So decided is this character that the experienced collector in the beds of Texas, Oklahoma and New Mexico will spend fully as much time in searching for favorable spots and localities, indicated by peculiar physical features, as in searching for specimens. This means that the members of a fauna inhabiting a generally unfavorable region concentrated around favorable feeding or watering places, or that perhaps intermittent streams gathered in sudden floods the scattered débris of life. Such implications are borne out by the physical content and nature of the beds.

In South Africa remains of the fauna of the *Tapinocephalus* zone, especially the great Pareiasaurians which lived in the localities where their remains are found, are always discovered as widely dispersed specimens, and rarely is there an association of two or more skeletons. Even the transported remains of the Dinocephalians and the carnivorous Therapsidans show the same wide dispersal. The implication, borne out by the monotony and homogeneity of the beds, is that the animals were free to range over wide areas in singularly identical conditions and that the stress of the environment, which either induced or permitted evolutionary changes, was exerted in the region of the highlands on the borders of the basin, or was the long swing of climate change from humidity in Ecca time to extreme aridity in the closing phase of the Karroo deposition in late Permian and Triassic time. The evident increase in the amount of sandstone and felspathic material toward the north reveals the continued presence of an upland of igneous rocks, undergoing rapid degradation, a condition which would include the necessary factors for a varied and variable environment; just such an environment as is associated with rapid evolutionary changes.

The sediments of the *Endothiodon* zone can hardly be distinguished from those of the *Lystrosaurus* zone by the physical characters. There is less of the sandstone, and the clays are more variegated and sometimes with ripple-marks, all indicating a progress in the general desiccation which seemed to be in progress throughout Karroo time, for the lowering of the water table would permit the formation of the higher oxides of iron, increasing the variety of colors, and the sands and ripple-marks indicate partial emergence. Such a change in conditions would bring the more rigorous conditions of the highlands down to the lower lands and the rate and variety of the evolution the vertebrates would respond to this stimulus. The change is also made apparent by the fact that the fossils are found concentrated in small localities to a far greater degree in this zone than in the one below; especially rich areas are found at Beaufort West, at the farm

Kuilspoort near Beaufort West, at Duneden, and at Victoria West. Evidence of the increasing rigor of the environment is shown by the fact that the great Pareiasaurians have assumed an armor of plates and spines which is always an evidence of advanced specialization, the Dinocephalians have disappeared, and the Dicynodonts have the teeth decadent (Endothiodonts) or completely reduced, except for the tusks in the male, and replaced by a horny sheath.

The *Cistecephalus* zone is characterized by an even greater proportion of red clays and sandstones in comparison with the greenish clays. Huene (1925[2]) compares these deposits with the variegated clays and sandstones of the European Keuper. The fossils are found in the red clays and are most commonly enclosed in calcareous nodules in which the bones are the accidental nuculei. This indicates the presence of desiccating pools, highly charged with dissolved calcium carbonate, to which the animals resorted for water or the food which was to be found at the edges. The Pareiasaurians have practically disappeared, only one specimen being known; the Dicynodonts are the most abundant form, extremely prolific in species, and indicating, if Watson is correct, a semi-desert condition; the carnivorous forms, Gorgonopsians and Therocephalians, are abundant in numbers and in kinds; the Cynodonts have made their appearance.

Evidently the increasing variety and rigor of the environment over the Karroo aggradation area either permitted the immigration of forms previously confined to the highlands or induced a rapid and vigorous evolution of the forms within the area. It is at this time that the comparison of the Karroo with the Great Plains area of the United States, made by Abel and Watson, is most fitting. A few plants of the *Glossopteris* type, a few freshwater shells, and rare specimens of fish have been found. This amazing lack of any remains, that can be considered as a possible food supply for the abundant reptilian fauna, leaves the source of the maintenance of the animals one of the most puzzling problems of the Permian of South Africa. The carnivorous forms would have preyed upon smaller carnivores and upon the herbivorous forms, but the ultimate food supply is not indicated.

The *Lystrosaurus* zone is generally conceded to be above the limits of the true Permian, but it presents features so interesting and directly connected with the problem of the evolution of the South African vertebrates that it may well receive consideration here. The physical character of the sediments indicates an apparent halt in the progressive change toward the intense aridity of the Triassic. The lower beds are variegated red shales and clays, with layers and patches of green and blue with abundant ripple-marks, rills marks, mud flows and so forth. In certain layers near Burghersdorf the author noted abundant cylindrical casts, showing a rough pitted surface and a bulbous enlargement of the lower ends. These casts stand vertically, or at all angles, in the clays, and can most reasonably be interpreted, as they have been by others, as the root stalks of some sort of vegetation. The author is informed that this type of root stalk is characteristic of swamp-living plants.

Near Harrismith the same zone is made up of red and gray shales with bones, either contained in calcareous nodules or coated with calcareous matter. At one place there is an unquestioned bone-bed with a predominance of the small amphibian, *Lydekkerina.*

Such appearance, both of the beds and the fossils, indicate swamp and lagoon conditions such as is so common in the Permo-carboniferous beds of the United States. The persistence of the same characteristics over large areas indicate the very general increase in the humidity or, as suggested by Huene (1925[2]), a rise of the water-table due to a temporary cessation in the sinking of the aggrading basin under its increasing load of sediment. The change indicated by the physical character of the beds is reflected in the dominance of a new type of Dicynodont, *Lystrosaurus*, considered by some authors to be aquatic but by others as more of a littoral type; by the disappearance of the Gorgonopsians and the Therocephalians; and by the increase in the number of the Cynodontia, a form better fitted to endure the vicissitudes of the changing environment. Their adaptability is further evidenced by their increase in importance in the upper Beaufort beds where the advance toward aridity is again evident.

Huene (1925[2]) has given a very full picture of the life and conditions of the basin during Karroo time. While the interpretation given above agrees fairly closely with his, the author would explain the changes in a different way. Huene assumes that the whole basin was continuously sinking under its accumulating load of sediment, but that the sinking was not uniform in rate. In consequence a time of slower sinking would allow an accumulation of material and the water-table would be lower, a time of more rapid sinking would permit the rise of the water-table and the accumulation of bodies of water upon the surface. It is conceded by all that the Karroo basin was sinking and that this sinking continued until the time of the Drakensberg flows and intrusions of basaltic lava, but the consistent increase in the amount of red material and in the amount of waters loaded with water-soluble salts speak very insistently of a progressive climatic change toward the development of wet and dry seasons and eventual aridity. The evident abundance of water during the time of the deposition of the *Lystrosaurus* zone may be explained on either hypothesis.

From the descriptions given of the region north of Rhodesia it is evident there was an area of aggradation north of the Transvaal and Rhodesian highlands and that the ice descended into parts of this at least. The slight knowledge that we have of the geology of the lake region of Central Africa and of the Congo basin suggests that deposits similar to those of the Karroo

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[1] But see foot note on page 147.

were laid down there. The evidence used by the various authors cited for the correlation of the beds is almost entirely based upon the physical characters—a few plant remains, a few fossil fishes, and a few invertebrates, collected from scattered localities, together with the single reptile (Haughton, 1924) make far too limited material upon which to build more than the broadest suggestions. The reptile, *Tangasaurus*, is considered by Haughton to be most closely related to *Youngina*, a form from the Middle Beaufort beds, *Lystrosaurus* zone; Nopsca (1924) considers it more closely related to *Saurosternon*, a form of uncertain relationships from the Lower Beaufort, *Cistecephalus* zone. Whichever of these two may be right, the specimen indicates a single fairly definite horizon north of the highland. Until far more evidence is accumulated, Huene's suggestion (1925[2]), that the South African fauna migrated across northern Africa and the Iberian Peninsula to appear in Russia and Scotland, must be accepted as a brilliant but unsupported hypothesis. This suggestion will be discussed in detail later, page 199.

THE PERMIAN OF NORTHERN AFRICA

Suess in his *Antlitz der Erde* (English edition, vol. IV) describes the Hercynian type of folding as present between Casablanca and Rabat in Jebelet, near Marakad (Marrakech), and in the Great Atlas. He notes that the Permian is almost always cut off from the older beds by an unconformity; this statement loses much of its force from the uncertainty as to the age of the beds which he accepts as Permian. Gentil's Provisional Map of Morroco, (1920,) shows the alignment of folds and the beds most clearly and M. Gentil has assured the author that the similarity to the Hercynian structure is most striking in the field. The continuation of the Hercynian folds into Africa is, however, still too much of a mooted point to permit its acceptance as even confirmatory evidence as to the age of any given beds.

Russo (1922[1],[2]) gives the following summary of the Permian (?) in central Morocco.

> Red, unfossiliferous conglomerates lie unconformably at an angle of 90° upon the Silurian and Devonian limestones at Kenifra and underlie the Jurassic farther to the west. These conglomerates are in all ways comparable to those described from Algeria by Flammand and from southern Morocco by Brives and Gentil, and referred by the writers to the Permian. The same conglomerates appear north of Kenifra in the basin of El Graar and the cliff Zaïane. Still further north they appear near Agouraï, Ito, Azrou and Aïn Leuh, forming a continuous band below the Jurassic of the region.
>
> To the west of Kenifra the conglomerates appear in the valleys of the Nellah and Neffik, and near Maaziz, Merzga and Camp Marchand. In these places a gypsiferous shale lying on the conglomerate is probably referable to the Triassic.
>
> Examined in detail, the conglomerate is seen to be an alternation of conglomerate with beds of more or less fine-grained sandstone which sometimes shows indeterminate traces of vegetation, much as in the similar beds of Spain and Portugal. In the lack of determinable fossils, Russo found it desirable to refer the conglomeratic beds, provisionally, to the Permian, but to regard the gypsiferous shales as Triassic.

> On the lower course of the Oum el Rbia similar conglomerates occur from Azemmour to El Arba and Mechra ben Abbou. Here the conglomerates are red, unfossiliferous, sub-horizontal and subordinate in amount to the red gypsiferous clay.
>
> In the High Atlas, red conglomerates and sandstones occur in patches from Demnat nearly to Agadir. In the peaks of Ourizan, Gondafi, Amserdin, Anremer and Noukra, there are violet-colored conglomerates, red sandstones, and limestones and violet shales.
>
> In eastern Morocco a heavy dark-red conglomerate, very similar to those described above, appears at the northern foot of the Djebel Grouz (Dj. Maiz, just north of Figuig). It is also unfossiliferous but has been provisionally referred to the Permian by Rosso.

Gentil (1917) described the Atlas Mountains as raised at the end of the Carboniferous as part of the Hercynian movement. The mountains were then eroded to a peneplain and the flanks and depressions buried in a terrestrial debris of deep red color. In 1918 he came to the conclusion that the sands, conglomerates and variegated shales of Algeria, which Pomel first placed in the Permian and later in the Triassic, are Permian in age. This reference he considered to be confirmed by their position below Triassic beds in the basin of Tafora, in Algeria, and their association with flows and tuffs of andesite. The association of terrestrial beds and eruptives recalls the similar condition in Central Europe.

Although only indeterminate plant remains, probably stems and needles of conifers, have been found, Gentil felt warranted in asserting that the beds are a lagoonary and continental phase of the Permian, but remarks that similar beds in Spain are inseparable from the Permian and he preferred to call the whole series, many hundreds of meters thick in the Atlas, central Morocco and the western Rif, Permo-triassic.

Permain of Madagascar

The sedimentary rocks of Madagascar are largely confined to the western side of the Island. Here there is a series of beds with thin seams of coal which has been referred to the Carboniferous. Above these beds, in the upper valleys of the Onilahay and Mangoky Rivers, and the valley of the tributary Sakamena, near Benehitra, there is a conglomerate with large blocks of crystalline rock which is considered by Boule and Du Toit as glacial in origin and similar to, or identical with, the Dwyka of South Africa. Above the conglomerate is a series of siliceous schists with concretions enclosing casts of plants and animals. In a series of papers Boule (1899, 1908[1], 1908[2], 1910) has given preliminary descriptions of the beds and the fossils. The plants have been identified as belonging to the *Glossopteris* flora, *Glossopteris major* Feist., *G. cyclopteroides* Feist., *Gangmopteris*, *Schizoneura*, by Boule, and Fritel (1920). The animals were considered by Boule to be related to *Atherstonia*, *Eryops*, *Urocordylus* and *Hatteria* and, perhaps, Dinosaurs. Upon the basis of this evidence the beds were referred to the Permian; certain beds of the upper part, originally ascribed to the Permian by Smith-Woodward on the evidence of the presence of the fish *Atherstonia*, have been shown to be Triassic in age. These specimens are now in process of careful study and description under the direction of Professor Boule; the author had an opportunity to examine them hastily and believes that he is violating no confidence or privilege in expressing the opinion, anticipated by Professor Boule, that the reptilian remains are of forms closely related to *Mesosaurus* and that the imperfect specimen of a Stegocephalian is more Triassic in general aspect than Permian.[1]

In his 1899 paper Boule calls attention to the evidence which shows that Madagascar was separated from Africa as early as the late Permian and was certainly separated during all the Mesozoic.

The fauna of South Africa is so large, and such recent and easily accessible lists have been published by Haughton (1925) and Huene (1925) that it seems unnecessary to repeat the enumeration. The same thing is true for the flora; a very satisfactory list can be found in Arber (1905).

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[1] Since this statement was put into print an article has appeared by Jean Piveteau (Paléontologie de Madagascar. XIII Amphibiens et Reptiles Permiens. Annales de Paleontologie, Tom. XV, Fasc. II and III, June, 1926), describing the geology of the Permian deposits of Madagascar and the amphibian and reptilian fossils. The amphibian material is identified as *Rhinesuchus cf. senekalensis van Hoepen;* a new genus and species of Mesosaurian, *Hovasaurus boulei* is described, and *Tangasaurus menneli* Haughton is identified. Upon the basis of this material the beds in Madagascar are correlated with the *Cistecephalus* and *Endothiodon* zones of South Africa.

CHAPTER XI

SUMMARY DESCRIPTION OF THE PERMIAN AND PERMO-CARBONIFEROUS OF AUSTRALIA, NEW ZEALAND, AND TASMANIA

The Permian of Australia and the adjacent islands has not as yet afforded any specimens of the tetrapod life. This fact is sufficiently striking to warrant the inclusion of a description of the beds; apparently there was no reason, either climatic or in the presence of terrestrial conditions, why such a fauna should not be present, and the explanation seems to be in actual geographical isolation. This is the more remarkable as Stegocephalians are present in the Carboniferous (*Bothriceps major*, s-w. from Airly in the Lithgow district) and the Triassic, Hawksbury sandstone.

In discussing the character of the beds the best-known sections, those of New South Wales, are taken as the starting point. The author has drawn largely from Süssmilch's excellent summary—*The Geology of New South Wales* (1922). His understanding of the beds and their sequence is due to the guidance, most kindly given, by Professor Sir Edgworth David and Professor Süssmilch, during his visit to Australia.

Süssmilch (1922) gives the following general section for the Permo-carboniferous and Carboniferous deposits of Australia.

Permo-carboniferous:
- Upper Coal Measures.
- Dempsey Series.
- Middle or Tomago Coal Measures.
- Upper Marine Series.
- Lower or Greta Coal Measures.
- Lower Marine Series.

Carboniferous:
- Upper Carboniferous. *Rhacopteris* beds and associated marine beds; Kuttung Series.
- Wallaroba Disturbance.
- Hunterian Disturbance; uncomformity and transgressive overlap on Carboniferous.
- Lower Carboniferous. Burrundi Series.

The Burrundi Series is entirely marine and passes in many places without disconformity into the terrestrial beds of the Kuttung Series.

The typical section of the Kuttung Series is shown in the Hunters River District and is given by Süssmilch as follows:

Glacial Beds.
Patterson Rhyolite.
Mount Johnstone Beds.
Martins Creek Beds.
Wallaroba Beds.

The lowest of the series, the Wallaroba Beds, begin with a conglomerate of igneous and metamorphic rocks, some of the blocks reaching a diameter of

18 inches; all are water worn. This bed reaches a thickness of from 1,000 to 2,000 feet and is succeeded by a heavy bed of volcanic tuff. It is because of the nature of the material in these beds that Süssmilch postulates the Wallaroba disturbance.

The Martins Creek Beds are made up of an alternation of lava flows, tuffs and conglomerates, attaining a thickness of 2,280 feet.

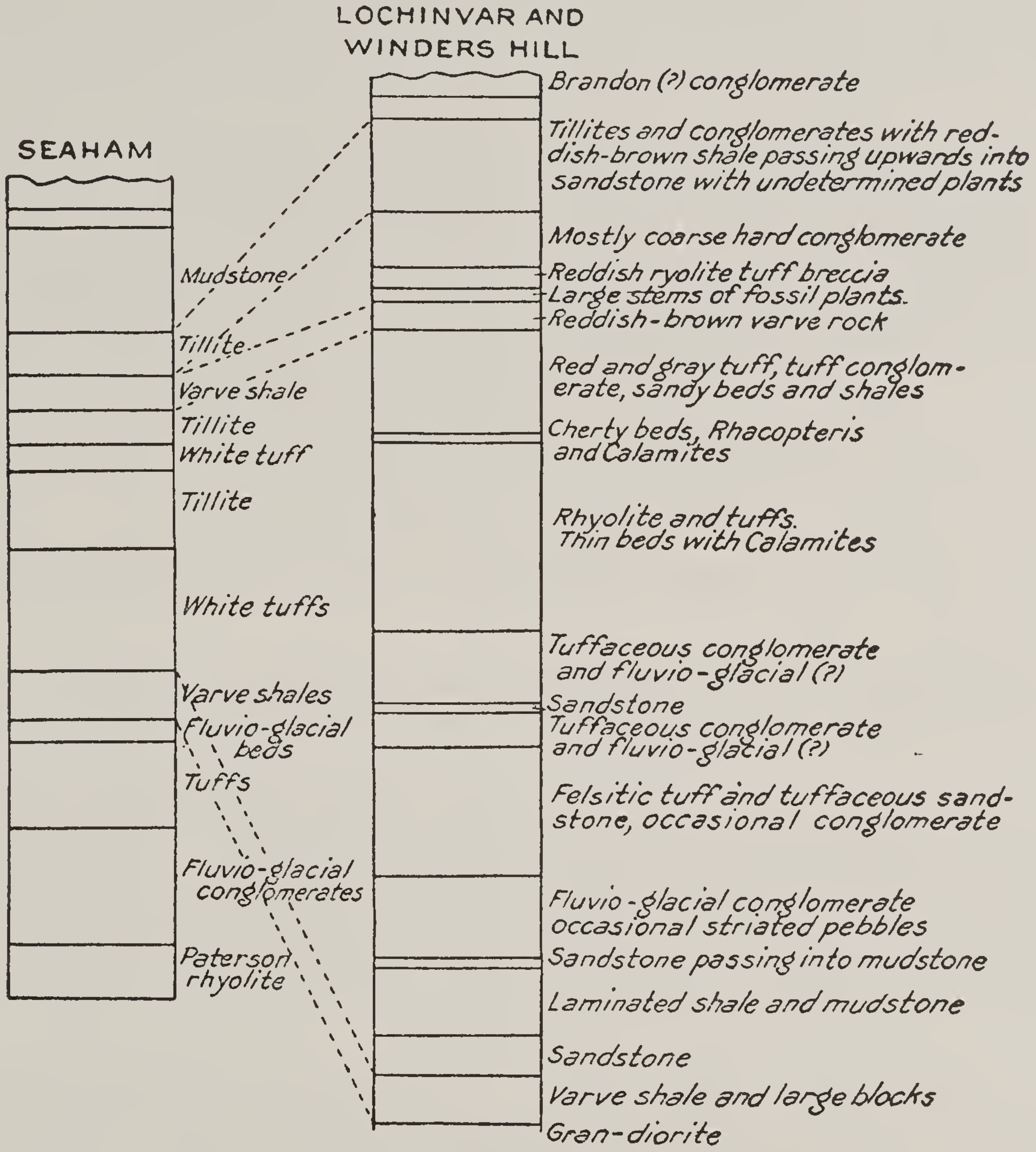
LOCHINVAR AND WINDERS HILL
SEAHAM
Brandon (?) conglomerate
Tillites and conglomerates with reddish-brown shale passing upwards into sandstone with undetermined plants
Mostly coarse hard conglomerate
Reddish ryolite tuff breccia
Large stems of fossil plants.
Reddish-brown varve rock
Red and gray tuff, tuff conglomerate, sandy beds and shales
Cherty beds, Rhacopteris and Calamites
Rhyolite and tuffs. Thin beds with Calamites
Tuffaceous conglomerate and fluvio-glacial (?)
Sandstone
Tuffaceous conglomerate and fluvio-glacial (?)
Felsitic tuff and tuffaceous sandstone, occasional conglomerate
Fluvio-glacial conglomerate occasional striated pebbles
Sandstone passing into mudstone
Laminated shale and mudstone
Sandstone
Varve shale and large blocks
Gran-diorite
Mudstone
Tillite
Varve shale
Tillite
White tuff
Tillite
White tuffs
Varve shales
Fluvio-glacial beds
Tuffs
Fluvio-glacial conglomerates
Paterson rhyolite

FIG. 21.—Sections of Carboniferous and Permo-carboniferous beds at Seaham, Lochinvar, and Winders Hill in New South Wales. After Süssmilch.

The Mount Johnstone Beds are tuffs, conglomerates and mudstones, 2,000 feet in all. The mudstones contain an abundant flora of Carboniferous forms. The abundance of plant life is further attested by the presence of a few thin seams of coal.

The Patterson Rhyolite is about 200 feet thick. With this extrusion the volcanic activity of Carboniferous time came to a close.

The Glacial Beds are composed of ice-dropped fragments, true tillite, lake clays and tuffs. The thickness varies; in the Seaham-Patterson District there are 7,000 feet, in the Currabula District 9,500 feet. The sections shown above are given by Süssmilch.

In the Glacial Beds occur the Varve Shales of which an interesting description and discussion is given by Süssmilch (page 92 and following). The Kuttung Series is followed with slight interruption by the Permo-carboniferous Beds, but David is of the opinion that a disconformable relation, at least, exists in all places even though it is not always evident; this is the trace of the Hunterian Disturbance.

The beds of the Kuttung Series carry the *Rhapcopteris* flora of the European middle Carboniferous and are generally considered by the geologists of New South Wales to continue to the end of the Carboniferous period, though some would suggest that the bulk of the beds may be considered as middle Carboniferous and the upper portion as upper Carboniferous.

The significant thing about the succession of the beds in relation to other regions of the Southern Hemisphere and of the world in general is the appearance of an undoubted glacial deposit at such an early stage, much earlier than in the most closely related regions, as South Africa and India. That the phenomena of glacial conditions was localized, even though it may have been the forerunner of the impending general glaciation of the Southern Hemisphere, is indicated by several things:

(*A*) The persistence of a typical Carboniferous flora, which may have easily existed in the same region as bodies of water with floating ice, or near the extremities of ice tongues reaching down from highlands.

(*B*) The possibility of local glaciation is shown by the relatively great accumulations of heavy conglomerates and the complete exclusion of the sea from areas previously occupied.

(*C*) The elevation during, or preceding, the deposition of the Kuttung Series, called by Süssmilch the Wallaroba Disturbance, culminated in volcanic outbreaks which were responsible for the flows and tuffs interbedded with the fluvio-glacial deposits of the Martins Creek and Mount Johnstone Beds. That the presence of active volcanoes did not prevent the presence of local glaciers or glacial conditions is shown by the fact that many of the interbedded mudstones are "undoubted glacial muds" (Süssmilch, page 92).

Permo-carboniferous time was characterized by the generally lowered surface of the land; this was in part due to a differential movement of the land, called by Süssmilch the Hunterian Disturbance, but conceivable as due in part, at least, to the extensive wastage of the uplands attested by the heavy conglomerates and later masses of finer detritus contained in the Carboniferous Beds. The Permo-carboniferous deposits, 17,100 feet in all, in New South Wales, are made up of alternate marine and terrestrial beds such as occur in North America at a slightly earlier period. Such a succession has been most satisfactorily explained by the assumption of a low lying land which by slight alternations of level would be either subject to invasions by the sea or the site of terrestrial accumulations. That the change from Carboniferous to Permo-carboniferous conditions was other than a local one and part of a world wide, or, at least, hemisphere wide, readjustment is shown by the radical change in both the flora and fauna.

The Permo-carboniferous beds lie in a great basin or depression in New South Wales which—

> "extends from the coast to the Blue Mountain Tableland, and from the Illawarra District to the southern end of the New England Tableland. Throughout the greater part of this area the Permo-carboniferous strata are covered by Triassic beds; a continuous outcrop of them occurs, however, around the edge of the basin except along that part of the coast between Coal-cliff and Lake Macquarie. In addition to this main basin, Permo-carboniferous strata are extensively developed along both the eastern and western flanks of the New England Tableland, but are quite absent in the southeastern and in the western part of the State." (Süssmilch, page 94.)

The Permo-carboniferous lies unconformably upon the Carboniferous and extends beyond it in transgressive overlap on to older beds. David (1914), however, does not regard this unconformity as of major importance.

The lowest portion of the Lower Marine Series, most clearly shown in the Hunter River District, is a bed of glacial sandstones and shales with numerous ice-striated pebbles and boulders—

> "these are not in any sense boulder clays or till, but are ordinary sediments into which, during their deposition, glacial pebbles have been dropped by floating ice. *It might be mentioned here that this is also the probable origin of the striated boulders and erratics which occur on several higher horizons in the Permo-carboniferous system of New South Wales.*" (Süssmilch, pages 95 and 96. Italics by the author.)

These beds grade upward into sandstones with plants which are overlain by shales carrying "occasional glacial erratics" and marine fossils, *Eurydesma*, etc. From this level to the top of the Lower Marine Series there is a succession of tuffs, lava flows, calcareous shales and sandstones.

The section in the isolated regions on the coast, on the Macleay River north of Newcastle, and near the Queensland border, is not known in detail.

The Lower Coal Measures, Greta Coal Measures of the Hunter River District, consist of fresh-water shales, sandstones and conglomerates, with two important coal seams. The shales carry the *Gangmopteris* and *Glossopteris* floras, the former dominant. The extension of the beds to the north on the western side of the New England Tableland and to the south, in the Illawara District, show little significant difference from the Hunters River District.

The Upper Marine Series was the most widespread, apparently, of all the Permo-carboniferous System; it overlaps most of the other formations. The lowest, Branxton stage, is largely made up of sandstones and shales with fossils of Bryzoa. The shale is filled with erratic boulders, some of large size (up to 5 tons in weight) which are frequently striated. Everywhere they bear the evidence of having been dropped from floating ice masses.

The Murree Stage begins with a calcareous conglomerate with included erratics (some up to 2 tons in weight, derived from regions to the southwest) and many marine fossils. This is followed by the Crinoidal Stage of shales carrying crinoids and pelecypods.

In the Western Coal Fields (Lithgow-Capertee District) the overlap of the Upper Marine Series is most apparent in the lowest member; a thick, coarse basal conglomerate lies directly "upon highly tilted Lower Paleozoic strata." The boulders of the conglomerate are apparently not erratic, but are derived from closely adjacent older rocks. In the Southwestern Coal Fields and in the Illawarra District the same conglomerate is covered by a more or less perfect series of marine shales and sandstones; in places, as in the Illawarra District, the beds are rich in marine invertebrates. The Upper Marine Series terminates in a succession of tuffs and lava flows.

The Middle Coal Measures, Tomago Series, is again a succession of fresh-water beds, formed of alternating coal beds, sandstones and shales. The *Glossopteris* flora occurs in these beds. The Dempsey series, above the Tomago Series, is well shown in the East Maitland District and differs from the Tomago in the absence of coal beds.

The Upper Coal Measures, most clearly shown at Newcastle, is a succession of coal beds, shales and sandstones, some of the shales being largely tuffaceous in composition. There is no evidence of glacial action or of glacial deposits. Apparently there was a continuous swampy or semi-swampy condition; Süssmilch pictures the situation as follows—

> "Along a wide coastal plain there was a development of plant growth in shallow marshes, the predominant type of plants at first being *Glossopteris* and *Sphenopteris*. This growth of lowly organized plant-like ferns was followed later by a spread of forest trees."

This might have been made a more vivid picture had the periodic submergences with the frequent abundant showers of volcanic ash and the really rapid filling of the basin, evidenced by the still standing trunks and stumps of trees, been described. Howchin (1920, page 1143) gives a rather striking picture—

> "While the highlands of Victoria, South Australia and Northwestern Tasmania were above sea-level and ice-capped, in Permo-carboniferous time, the great Sydney coal basin was slowly sinking below sea-level."

In the Bellambi Colliery, 43 miles south of Sydney, a fall of the roof disclosed a series of footprints in the strongly ripple-marked top shale. These footprints are distinctly reptilian and were compared by Mr. Dunn to the *Ichnium gampsodactylum* of Pabst from the Rothliegende of central Germany. The shale is part of a ripple-marked bed which has been traced inland as far as Mount Keira. It is in the upper horizon of the Upper Coal Measures; the *Glossopteris* flora has not been found above the level of this coal seam.

THE PERMO-CARBONIFEROUS IN QUEENSLAND

Exposed beneath Brisbane and Maryborough are 2,000 feet of greywackes, sandstones, carbonaceous shales and conglomerate, with some impure limestone. The beds have been, in part, folded and intruded by basalt (greenstone). Interbedded with the sedimentaries are lava flows and beds of tuff.

The Gympie Series, of southwest Queensland and near Rockhampton, includes a thick bed of limestone with a marine fauna which is the same as that of the Lower Marine Series of New South Wales (David, 1914). In some of the shale beds of this series are large boulders of greywacke and other igneous material which are truly erratics but there is no till; the boulders are considered to have been borne by ice and dropped in their present position.

The Lower Bowen (Dawson River) Series is exposed in the valley of the Dawson River inland from Maryborough and Rockhampton. The series begins with marine beds carrying ice-borne erratics; these are succeeded by volcanic material, terrestrial sediments with coal (anthracite), marine beds again and finally terrestrial beds carrying the *Glossopteris* flora. David considers that the coal bearing portion of the series is equivalent to the Lower Coal Measures (Greta Coal Measures) of New South Wales.

The Middle Bowen Series is mainly exposed in the valley of the Bowen River, a tributary of the Burdekin which empties into the ocean a few miles north of Bowen. The beds are sandstones with marine fossils, shales, a little coal and conglomerates. The conglomerates contain some erratics, probably ice-borne boulders, but there is nothing resembling a tillite. These beds are apparently the equivalent of the Upper Marine Series of New South Wales.

The Upper Bowen Series, exposed in the Bowen Coal Field and north, near Townsville and Cooktown, is largely made up of shale, sandstone with coal and intrusive lavas. David regards these beds as equivalent to the Upper Coal Measures (Newcastle Coal Measures) of New South Wales. At Townsville a small area of Permo-carboniferous comes to the surface from beneath the deposits of the coastal plain, its extension to the east carries it "out to sea beneath the coral reefs of the Great Barrier" (David, 1914, page 271).

In his description of the Bowen formations, David (1914) recognizes only two divisions, the Upper and the Lower Bowen; his section, in which the elements described above can be easily recognized, is as follows:

Upper Bowen	Tolmie Coal Measures.
	Slight unconformity.
	Marine shell beds of Capella.
	Slight unconformity.
Lower Bowen	*Glossopteris* beds of Oakey Creek and St. Mary's.
	Marine shell beds of Oakey Creek and St. Mary's.
	Sedimentary rocks with an 11-foot seam of anthracite.
	Lower Marine Series followed by a volcanic series.
	Marine beds similar to the Gympie with ice-borne boulders.

Walkom (1919) uses the terminology of the New South Wales geologists, recognizing in Queensland the—

Upper Coal Measures.
Upper Marine Series.
Lower Coal Measures.
Lower Marine Series.

Permo-Carboniferous Deposits in Victoria

The glacial beds of the Lower Marine Series are the only portion of the Permo-carboniferous System which appear in Victoria. The deposits are tillites mingled with conglomerates, sandstones carrying ripple-marks, and fine-grained shales. The upper part of the deposit is formed by sandstones carrying the *Glossopteris* flora; there is a total thickness of 2,000 feet. These beds lie on an old eroded surface which shows some evidence of cutting by glacial action, as at the Werribee gorge. The striated surfaces and the material of the tillites show a movement of the ice from south to north. Outcrops of the Permo-carboniferous occur over much of Victoria; they are recognized at Nhel beneath the Tertiary covering, at Heathcote and Bacchus Marsh near Melbourne, at Beachworth further to the east, and near the New South Wales border.

Permo-Carboniferous Deposits in South Australia

Howchin (1918) says the Permo-Carboniferous deposits of South Australia are entirely terrestrial, "laid down by land-ice under very severe glacial conditions." Subsequent erosion removed much of the material but extensive deposits still occur in (1) the southern half of the York Peninsula; (2) the eastern side of Kangaroo Island; (3) the whole of that portion of the Jervis Peninsula which lies south of the Willagunga River (approximately the portion south of the railroad line leading from Adelaide to Melbourne); (4) the Mount Compass District; (5) in the valley of the Finness River, near Ashbourne and as far as the line of the Strathalbyn railway (i. e. south of the railroad line from Adelaide to Melbourne). Detailed descriptions are given by Howchin in his *Geology of South Australia* (1918).

At Hallett's Cove, south of Adelaide, there are polished surfaces of Cambrian rocks with striae showing a movement of the ice from a little east of south. Overlying these surfaces are 900 feet of conglomerate, sandstone and shale, but no coal and no marine beds. Howchin (1920) emphasizes the fact that no marine beds of Permo-carboniferous age have been found in South Australia or Victoria. The beds are either glacial—"land ice on a large scale"—or fluvio-glacial as shown by "the interstratification of true tillite with mudstones, sandstones and conglomerates." He suggests that it is probable that the greater part of South Australia, Victoria, Bass Strait and northwestern Tasmania formed a continuous landmass in Permo-carboniferous time.

Permo-Carboniferous Deposits in West Australia

The Collie Coal Field in the southwestern part of West Australia, south of Perth, is a small portion of a basin preserved from erosion by trough faulting. The shale associated with the coal carries the *Glossopteris* flora. North of Perth, on the Irwin River, there are glacial beds overlain by fossiliferous marine beds including some limestone, and these, in turn, by brown clay shale with seams of coal.

On the Gascoyne, Wooramel, and Minilya Rivers there is a well-marked glacial horizon, the Lyons conglomerate, which underlies the bulk of the Carboniferous strata. There is now little doubt that this glacial horizon is identical with that of the Bacchus Marsh, in Victoria, Hallett's Cove in South Australia, Wynard in Tasmania, and Lochinvar and Dempsey in New South Wales. All the beds above this glacial horizon might fairly be reckoned as Permo-carboniferous, if not Permian.

> "In the Kimberley District of Western Australia the glacial horizon has not been identified definitely, and perhaps does not exist there, but the fossils are essentially similar to those above the glacial horizon of the Lyons conglomerate, and may therefore provisionally be classed as Permo-Carboniferous and even Permian" (David, 1914, page 269).

Strata similar to those exposed in the Kimberley District extend as far as the Victoria River in the Northern Territory of South Australia. The marine strata are here associated with fresh-water shales containing *Glossopteris*. The same formation has been traced to Arnheim Land and the islands northeast of Darwin and even, perhaps, to Groote Island.

Permo-Carboniferous Deposits in Tasmania

Howchin (1920) says that there—

> "is a very close analogy in the lithological features between the Victorian and Wynard sections, and it is probable that the latter represent the southern extension of the terrestrial ice-sheet which had its greater development in the region now represented by South Australia and Victoria."

This is a little difficult to reconcile with his previous statements as to the movement of the ice, unless it be understood that by "extension" he means a portion of the great mass of ice and does not refer to his motion.

In southern Tasmania erratics occur in a dark-colored mudstone carrying marine fossils, or occur as beds closely associated with beds of marine sediment—

> "giving evidence that the glaciers in those localities came down to sea-level and, together with shore-ice, became the means of distributing the morainic materials from the adjacent land over the sea floor" (Howchin, 1920).

Again, from the same author—

> "It is significant that in Northern Tasmania as well as in Victoria and South Australia, the ice sheet was traveling from south to north, which proved that the one center of radiation was to the south of the continent and is now submerged."

Howchin (1920) describes Tasmania as about half covered by glacial deposits.

> "Tasmania, at that period, appears to have formed a coastal fringe bordering a mainland, as the sediments show alternating conditions of dry land, fresh water, carbonaceous swamps and shallow seas."

The northern portion of the Island was largely occupied by land ice for the deposits in that region are erratics up to 5 feet in diameter, tillite, conglomerates, and thin sandstones; 1,200 feet in all at Wynard. Three pavements at different levels showing striations have been noted by David; the striations and the nature of the erratics show the movement of the ice to have been from the south and the south-southwest.

David (1914) gives the following general section for Tasmania:

Upper Coal Measures, lacking.
Upper Marine Series.
Equivalent of the Lower Coal Measures, Greta.
Lower Marine Series.
Tillite and glacial conglomerate.

The Mesozoic rests directly upon the Upper Marine series. The equivalent of the Lower Coal Measures, Greta, is much reduced in importance and there are but few coal beds. The Lower Marine is very heavy, at least 600 feet at Wynard. The tillite and conglomerate reach a thickness of 800 feet at Wynard; the three layers of tillite are separated by interglacial beds. David (1914) says—

> "Each tillite horizon can be correlated with those of Victoria, and almost certainly with those of South Africa."

In summary David (1914) says of the conditions in Australia and Tasmania:

> "(1) In regard to the paleogeography the ice, which glaciated Tasmania, Victoria and South Australia, came from the south from a land probably a local extension southward into the Southern Ocean, of the Australian continent. * * * In Western Australia, the glaciation is thought to have come from the southeast, from local highland near the southern end of Western Australia. In Eastern Australia, the region affected by the glaciation was a landscape apparently of low relief, but we know nothing of the height of the gathering ground of the ice sheets on the now sunken part of the continent, where the eastern end of Jeffrey's Deep shows a depth of 3,000 fathoms. Possibly the great bank recently discovered, which lies about 200 miles south of Tasmania, and which rises from great ocean depths to within 500 to 600 fathoms of the surface, formed part of a high southeastern margin of Australia, extending from this bank to Kangaroo Island in Permo-Carboniferous time. This was no doubt in part a gathering ground for the inland ice. In New South Wales, there seems to have been local alpine glaciers. In southwestern Western Australia, there seems to have been a local ice sheet.
>
> "(2) There were at least three interglacial phases in Australia, probably to be correlated with those of Africa.
>
> "(3) The fauna especially in the disappearance of Carboniferous reef-forming corals suggests general refrigeration of the seas, while the flora of the coal seams is not inconsistent with that of a climate like that of Macquarie Island.
>
> "(4) Snow-line touched sea-level, probably near 40° S. latitude in Permo-Carboniferous time, and glaciers came down to sea-level at about 34° S. latitude.
>
> "(5) This may demand a fall of temperature as compared with the present of about 10° C."

The following table, adopted from David, shows the relation of the beds in different parts of Australia and Tasmania:

New South Wales.	Queensland.	Western Australia.	Victoria.	South Australia.	Tasmania.
Upper or Newcastle Coal Measures.	Upper, Bowen Coal Measures.	Collie Coal Field.			
Dempsey Series.					
Middle or Tomago, East Maitland Coal Measures.					
Upper Marine Series.					
Lower or Greta Coal Measures.	Dawson Coal Measures.				Mersey Coal Measures.
Lower Marine Series.	Gympie Series.		Bacchus Marsh.	Hallets Cove.	Wynard.

W. S. Dunn (1914, page 295) emphasizes the difference between the fauna of Eastern and Western Australia:

> "One of the most prominent features of the Eastern Australian Permo-carboniferous faunas is the absolute absence of any Carboniferous species, whereas in the west, together with the Indian species and local varieties, there are Carboniferous types such as *Orthis resupinata*, *Rhipodomella*, *Productus semi-reticulatus*, *Leptaena analoga*, *Phillipsia*, etc.—forms which in Eastern Australia are confined to the Star beds of Queensland and New South Wales, beds separated from the Permo-Carboniferous of that region by a well-marked unconformity. Taking into consideration the fact that the so-called Permo-Carboniferous sedimentation of both eastern and western Australia was initiated by glacial stages which must be regarded as synchronous, this mingling of faunas in Western Australia points to a direct communication with the Permo-Carboniferous coast line of the Himalayan and Salt Range Region. The fact that certain *Producti*, *Pectinidae*, *Terebratulidae* and *Spiriferidae* of the West have a close resemblance to the Eastern Australian types may, perhaps, be regarded as instances of parallel development, rather than of specific identity.
>
> "The Permo-Carboniferous of the Northern Territory has western affinities."

He notes also that the fauna of the eastern region varies little in character in New South Wales, Queensland and Tasmania.

The extreme poverty of the coelenterate fauna, all reef corals absent and only a few solitary corals present, is attributed to the cooling of the waters by glacial conditions.

The Pelecypods show the endemic character of the eastern fauna most strikingly with many purely unique genera. *Eurydesma* has been found elsewhere in the "olive shales" of the Himalayas and in the Southwest Protectorate (formerly German Southwest Africa) in South Africa.

PERMO-CARONIFEROUS DEPOSITS IN NEW ZEALAND

The Permo-Carboniferous horizon in New Zealand is still so much a disputed question among New Zealand geologists that it is hardly profitable to discuss it, other than to consider its possible presence as an indication of the eastern border of the land upon which collected the terrestrial deposits of eastern Australia. The history of the discussion and of various opinions which have been expressed concerning the age of the Maitai Beds has been summarized by Bell, Clark and Marshall (1911), by Marshall (1912), Trechman (1917), Reed (1921) and Morgan (1922); it need not be repeated here, especially as it is covered rather fully in the first two papers cited above.

The whole Maitai Series, or System, apparently includes deposits from the Carboniferous to the Trias-Jura with no recognizable unconformity in the section. It is reasonable to assume that the series includes deposits equivalent in age to the terrestrial beds of eastern Australia. Morgan (1922) restricts the portion referable to the Permo-carboniferous to a small exposure southeast of Nelson, in the South Island, and a portion of D'Urville Island, which is a direct continuation of the mainland. The Maitai Series, as a whole, is a "succession of conglomerates, sandstones, graywackes, argillites, shaly mudstones, and limestones, with a local development of contemporaneous igneous rocks." (Bell, and others, 1911.)

The series has been much folded and the structure is difficult to interpret. McKay, according to Trechman, considers, "with considerable reserve," that the rocks near Nelson were "arranged in a synclinal with the main axis N.NE. and S.SW." Locally the beds have been much metamorphosed.

The Maitai limestone which is probably the most nearly representative of the Permo-carboniferous than any other part of the series is best seen in the Wairoa Gorge near Nelson. Here the limestone is "much jointed, fissured, slickenslided and crushed, and has many veins running through it, which are sometimes seen to be repeatedly faulted on a small scale." It has been in part metamorphosed and serpentinized. The fossils appear to be confined to the upper part where it joins the Maitai slates and greywackes to the east.

Trechman made a considerable collection from this limestone and concludes that fossils indicate a Permo-carboniferous age—

> "All the ten genera I have described, with the exception of the comparatively unimportant *Serpulites*, occur in the marine Permo-Carboniferous of New South Wales.
>
> "The evidence, therefore, of the fossils of the Maitai rocks, few as they are, is overwhelmingly in favour of a correlation of these beds with the marine Permo-Carboniferous of New South Wales and Tasmania.
>
> "The absence of certain familiar fossils of Australia and the Salt Range, such as *Eurydesmus*(*a*), *Conularia*, *Aviculopecten*, etc., may be noticed, but their absence may be explained on geographical or bathymetrical grounds. The Boulder Bed of the Salt Range is equally wanting in some forms, but Waagen does not hesitate to correlate its fauna with that of the Permo-Carboniferous of Australia."

Trechman notes that the reported occurrence of *Glossopteris* in the Mount Potts region has been shown to be erroneous and that the flora is really of late Triassic or Rhaetic age. He continues—

> "since no trace of *Glossopteris* or any other plant is recorded from the Maitai rocks the paleobotanical evidence is removed. Further, although several coarse conglomerates occur in the Maitai Series, nothing for which a glacial origin can seriously be claimed has been found. The Permo-carboniferous of New Zealand differs from that of South Africa, Australia, Tasmania, the Falkland Islands, South America, or other regions of Gondwanaland in the absence of glacial beds or of a *Glossopteris* flora. There is no trace in New Zealand of a non-marine, plant-bearing Permo-carboniferous series, and there seems no prospect of any turning up. The beds appear to be entirely marine, but were evidently deposited not far from some land mass of continental dimensions.
>
> "The conclusion, therefore, is that although the New Zealand area formed no actual part of Gondwanaland, it lay during the Permo-carboniferous period not far from the shores of this or some similar great land mass which supplied the material which built up the Maitai Series.
>
> "In no part of New Zealand has definite evidence of any unconformity between the Maitai and the Trias been found, and so it is possible that uninterrupted marine conditions persisted from the Permo-carboniferous times through the Trias and on into the Jurassic period."

Morgan, in his notes upon the Geological Map of New Zealand (1922), says that much of the gneiss and schist of South Island (Otago and Westland districts) passes upward into Triassic-Jurassic beds with a decreasing degree of metamorphism and apparently without unconformity. The diorite intrusives are regarded by Park as of "late Permian, or perhaps Triassic age" (personal communication to Morgan). Morgan summarizes the history of the classification of the Maitai beds and comes to the final conclusion that they are Permian or Permo-carboniferous. He states that as yet no Paleozoic rocks have been found on the North Island, and relegates all of Hector and McKay's Carboniferous on the North Island to the Mesozoic, the Hohanui Series. The Dun Mountain District, near Nelson, is the only place where paleontological evidence exists for the Permian or Permo-carboniferous age of the Maitai; this evidence is entirely in the form of marine fossils but the absence of fossils of land plants does not disprove the possibility of land connections, as conglomerates occur in many of the Paleozoic deposits. He concludes much as does Trechman:

> "During the Paleozoic period, then, New Zealand was at times the foreshore of a great continent (Gondwanaland) and at times probably formed part of the continent itself."

CHAPTER XII

SUMMARY DESCRIPTION OF THE PERMIAN AND PERMO-CARBONIFEROUS IN SOUTH AMERICA

On the continent of South America the Permian and Permo-carboniferous are known in both northern and southern Brazil, in Uruguay, perhaps in the province of Buenos Aires in the Argentine Republic, and with considerable less certainty from Paraguay and the western part of the Argentine Republic.

The most thoroughly explored portion is that of southern Brazil. The geology has been made known largely through the reports of I. C. White (1908) and Branner (1919). Both of these authors give abundant references to the literature; the bibliography in Branner's description of the geology of Brazil is exceptionally complete and a good preliminary geological map accompanies the paper.

As a basis for the discussion of the beds the accompanying table made up from the various reports by I. C. White, Guillemain, Bodenbender, Branner, Kurtz, Frech, and others, showing the general sections in various parts of South America and their relation to the deposits in other parts of the Southern Hemisphere is inserted. (See page 181.)

The Permian of South America is typically developed in Brazil; it is readily separable into upper and lower portions. Branner (1919, page 211) says that in northern Brazil the line between the two is marked by a well-developed unconformity in the Sierra Grande Series where it is exposed in the Sierra Grande between the States of Piauhy and Ceará. The relative age of the two parts is determined by their position alone, as there are no fossils. In the southern states the upper Permian is characterized by the presence of the remains of *Mesosaurus* and *Stereosternum* and the abundance of siliceous concretions, while the lower Permian carries the coal beds and a (*Glossopteris*) flora, with an accumulation of glacial-formed material in its lower part.

Permian exposures are mapped by Branner through the whole of eastern Brazil and are indicated as probably present on the western side of the Rio Araguaya, in Grao Pará and Matto Grosso. He indicates in his text (1919, pages 211 and 212) his belief that they occur throughout the valley of the Rio Paraná because of the occurrence of beds and fossils in northern Paraguay and in southwestern Matto Grosso (Acre District). Doctor M. Doello-Jurado, Director of the Museo Nacional in Buenos Aires, informed the author that vertebrate material, possibly referable to *Mesosaurus*, had recently, 1924, been found near the Argentine-Bolivia boundary line.

The brief descriptions given in this paper are largely adapted from Branner's descriptions with some material drawn from I. C. White and other writers.

Table showing the Permian and Permo-carboniferous Beds in South America.

		India.	Queensland.	Victoria.	New South Wales.	Tasmania.	South Africa.	Argentina.	Brazil.	Uruguay.[1]
Triassic.	Cosmopolitan flora.	Umia (Cutch). Jabalpur. Khota Maleri. Panchet.	Ippswich beds. Burrum beds.	Bellarine coals.	Upper Clarence River. Hawkesbury (Boulder beds). Lower Clarence River.	Upper Jerusalem beds.	Cave sandstone. Red beds. Stormberg.	Calchenta (Cacheuta).	São Benito Series. Eruptives of Serra Geral. São Benito sandstone. Rio do Rasto red beds with *Scaphonyx* and fossil trees.	Heavy, white, red and variegated sandstone in northwest departments with inswept agate, chalcedony and siliceous wood. Frequently clay-iron concretions.
Upper Permian.	Glossopteris (Gangmopteris) flora.	Damuda. Raniganj. Barakar.	Bowen River Coals.	Bacchus Marsh Series.	Baltimore and NewcastleCoal Series.	Mersey and Potters Hill beds.	Beaufort beds.	Red beds and sandstone.	Passa Dois Series. Rocinha limestone. Gray and variegated shale beds of Estrado with quartz concretions and sandstone strata, fossilwood, and crustaceans. Black Iraty beds with *Mesosaurus* and *Stereosternum*.	Red and gray limestone of Passa Maria Isabella (Jaguaron Chico). Red, generally sandy, beds of Cerro Largos (e. g. Passo Arena and north of Melo). Silicified wood. Calcareous sandstone, mostly gray green, not heavy (Melo). Clay with sandy intercalations. Generally white and variegated sandstone (Melo and north border). Variegated shaly sandstone with beds of dolomitic limestone (Melo, Campo Menessa). Carbonaceous shale of Melo. Shale with saurian remains in Campo Menessa. Shale in Valley of Jagueron Chico.
Lower Permian.		Karharbari.			Upper Marine (glacial) Greta Coal.		Ecca Beds.	Coal, shale and gray arkosic sandstone.	Tubarão Series. Palermo shale, Rio Bonito beds, sandstone with coal layers and *Glossopteris* (*Gangmopteris*).	Sandstone, generally white and variegated (especially rosy) (North border of Fraili Muerto and Campo Silveira). Beds of sandstone. Clay shale and platy clay-sandstone with numerous footprints. Coal in borings on north border. Quartzite. conglomerate and arkose on east and south borders of Uruguay Basin (Querebracho, road to Fraili Muerto and Silveira, road Melo-Cerui).
		Talchir, glacial.	Bowen River Marine, glacial.	Bacchus Marsh conglomerate, glacial.	Lower Marine (glacial).	Upper Marine beds with coal, glacial.	Dwyka, glacial.	Basal conglomerate (glacial).	Orleans Conglomerate (glacial). Sandstone with shale.	Fraili Muerto glacial conglomerate. Blackish gray clay shale, partly sandy (Fraili Muerto and road Melo-Cerui).
Pre-Permian.					Lower Marine.	Marine.		Retamito (Devonian) and granite.	Devonian and granite.	Devonian.

---

[1] Guillemain, 1912.

In the State of Piauhy the rocks of the Sierra Grande Series, below the unconformity, are conglomerates, sandstones and limestones with calcareous shales. The sandstones are often cross-bedded and so far as known the whole sequence is totally unfossiliferous. Above the unconformity the rocks are horizontal, reddish calcareous sandstones and shales with identifiable remains of *Psaronius* and *Sigillaria* in the upper portion. A similar sequence appears on the eastern side of the Sierra Grande in the State of Ceará.

In Maranhão the Permian lies directly upon the granite and crystallines, as it does to the east of this region. The series begins with a bituminous shale and shows a sequence of marly shales, sandstones, some red and spotted, others gray and cross-bedded; the upper member is a layer of green and chocolate-colored shales, limestones and white sandstones.

In Pernambuco a few infaulted remnants of Paleozoic are referred provisionally by Branner to the upper Permian—

> "because they are stratigraphically in the place occupied by the Permian bed at Aracy (Bahia)."

In Alagôas a small area of Permian red shales shows in the valley of the São Francisco River and various outliers seem to connect this exposure with the exposure in Pernambuco.

In Sergipe the Permian appears to be included in the, as yet, undifferentiated Paleozoic. Branner (1919, page 321) says—

> "The Sierra Itabaiana is a monoclinal ridge of quartzites resting on the Archean rocks and outcropping eastward to the ocean. Above the quartzite are limestones, shales and sandstones that continue up into and through the Cretaceous."

The plateau watershed, composed of horizontal limestone and sandstone, which lies between Goyaz and Bahia, extends northward into Maranhão and Piauhy and southward as far as Pyrenopolis and Formosa and then between the Rio S. Marcos and Rio S. Bartholomeo to near Patrocino, where the rocks connect with those of the upper Permian horizon of Minas Geraes. Branner places these rocks in the upper Permian and gives as reason for his conclusion that they extend west in Pará and Matto Grosso. Matto Grosso is as yet little known, geologically, but Permian rocks are known to occur on the border line between this State and Paraguay, and there is evidence that they occur in the mountains of the little known Acre district, west of Cuyaba. As indicated above, Branner believed that the Permian was continuous beneath the valley of the Paraná.

In Bahia there is a lower limestone which Branner called the Salitre, placing it originally in the Triassic-Jurassic but concluding, in 1919, that it is a northern extension of the lower Permian limestone of the states to the south. Shales with Permian fossils have been located at Jacu a few kilometers east at Aracy, and 12 km. south of Bom Conselho, in eastern Bahia.

In Minas Geraes there is a broad expanse of Permian which apparently includes both the upper and lower portions, but the differentiation is some-

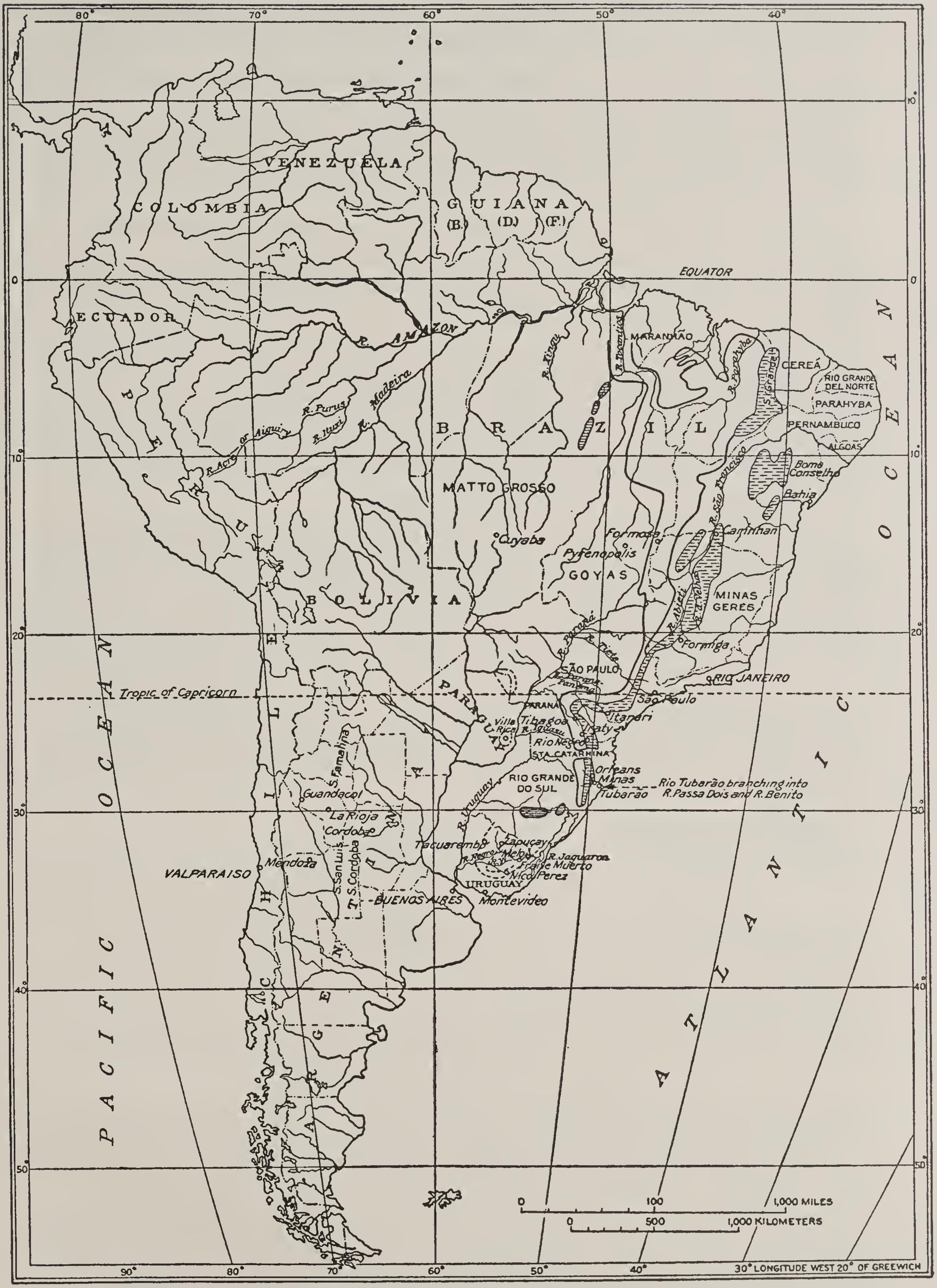

FIG. 22.—Sketch map of South America showing localities mentioned. Lines enclose lower Permian; dashed areas, upper Permian.

what uncertain. The glacial horizon of the States to the south is continued into Minas, but beyond this the horizon can not be traced to the north or to the east. The rocks are conglomerates, shales, sandstones and limestones, largely of fresh-water and terrestrial origin.

In Paraná there is lower Permian sandstone and conglomerate with evidence of glaciation, overlain by upper Permian shales, sandstones, flints and coal with fossil plants.

In Santa Catharina there is lower Permian with coal, west of the Rio Turbarão and glacial beds west of the Rio Negro, typically at Orleans, where there is a boulder bed 3 meters thick exposed near the river, with boulders 20 to 30 cm. in diameter.

In Rio Grande do Sul there is lower Permian composed of sandstone, shale and coal beds; some of the beds are fossiliferous.

In São Paulo the lower Permian lies upon the Devonian and Archean; it consists of sandstone and shale and of glacial beds. Above is the upper Permian with *Mesosaurus* and *Stereosternum* and the siliceous beds and concretions characteristic of the Upper Permian.

The glacial conglomerate and the terrestrial beds of the Turbarão and Passo Dois Series are widespread in the southern States, but become less distinctive toward the north. The Iraty Black Shale, which is so persistent from São Paulo southward, becomes limey north of Tebagay, in Paraná. Near Theriziana, in São Paulo, these beds become a fairly pure limestone and were considered by Derby to be marine in origin. South of Tebagay the beds are apparently purely terrestrial. The bones of *Stereosternum*, teeth of labyrinthodonts, and shells occur in both the limey phase and the terrestrial phase of the Iraty Black Shale. From these beds David White (in I. C. White, 1919) identified—

Rosellinites gangmopteroides.
Hysterites brasiliensis.
Phyllotheca griesbachi.
  mulleriana.
  sp.
Glossopteris browniana.
Vertebraria?
Gangmopteris obovata.
Derbyella aurita.
Arberia minasica.
Noeggerathiopsis hislopi.
Cardiocarpon seixasi.
  moerianum.
Voltzia ? sp.
Hastimima whitei.

This list, according to White,

> "proves the Tubarão series to be closely related to the Lower Karroo or Ecca Series of South Africa, as well as to the Karharbari group of the Gondwana System of India."

The Estrado Nova Beds are gray and variegated shales and sandstones with nodules of silica, crustaceans (according to Girty and Stanton) and shells.

The Rocinha limestone is covered unconformably by the red sandstone of the Triassic. Remarking on these beds, I. C. White (1908) says—

> "The close identity, not only of the fossils of the Santa Catharina and the Karroo Systems, but also the general resemblance of the stratigraphic and lithological features found in the two systems as well as the Gondwana System of India so far as the lower and upper members are concerned, certainly lends great plausibility to the view that the

southern continents must have been united in Permian and Triassic time by a great land connection now submerged, which Suess has termed Gondwana."

White seems to suggest that the middle Karroo horizon, the Beaufort, has not as yet been discovered in Brazil; his wording is not clear and may intend to suggest that it is absent. However, he notes the identification of *Erythrosuchus*, an upper Beaufort form, by Smith-Woodward, as showing the parallelism between the two regions. In further discussing the beds I. C. White says (1908)—

> "No evidence of the existence of marine beds was observed in either the Permian (Carboniferous) or Triassic deposits of Santa Catharina or Rio Grande do Sul, and hence it is quite probable that the rocks in these states may be of fluviatile and lacustrine origin. Northward, however, in northern Paraná and São Paulo, the Iraty and Estrada Nova beds become limey and hold fossil remains, of which Dr. Derby says (in extract from a letter) 'there are species of *Schizodus*, *Conocardium*, *Mytilus* (*Modiola*), and *Astartelle* ?, with a number of undetermined genera that look queer in the horizon. There are no Brachiopods, Aviculoids, Pectinoids, Lima-Arca or Allorisma-like forms.'
>
> "It is barely possible that the great climatic (glacial) and physical changes preceding or inaugurating Permian time in South Brazil, as evidenced by the Orleans conglomerate may have given origin to a series of large inland lakes and lake-like rivers, along which the Permian and Triassic deposits accumulated partly as fluviatile and partly as lacustrine sediments. That marine conditions existed in the interior of Paraná in Devonian time is certain * * * but whether or not the sea had retired permanently from Paraná and São Paulo, previous to the dawn of the Permian time, is not certain owing to the problematical nature of the animal remains found in the Permian limestones of Paraná and São Paulo."

David White (in I. C. White, 1908) notes the uniformity and extraordinary degree of specific identity of the *Glossopteris* flora in all places where it is known as indicating connecting land upon which it could migrate. He says (page 387)—

> "It is therefore now recognized that *Gangamopteris* flora probably owes its origin to the existence, for a time, in Gondwana-land of a glacial climate which either exterminated or drove back and held in check for a considerable period the cosmopolitan flora, or so much of it as was not able, by mutation or adaptation, to withstand the rigor.
>
> "Meanwhile the older Gondwana flora, offshoots of the hardier elements in the northern flora, developed and distributed themselves in both hemispheres. Though it is not supposed that they came into being under actual glacial conditions, there is hardly room for doubt that they appeared while the region was still cold and quite inhospitable to the contemporaneous northern, or cosmopolitan, types."

Permo-Carboniferous in Uruguay

The best published accounts of the late Paleozoic deposits in Uruguay are those of Guillemain (1912) and Walther (1919). Guillemain reproduces on a reduced scale a good map of the country by Jannash and gives a bibliography of 20 publications. He describes the Permo-carboniferous or Permian Basin of southern Brazil as extending south as far as the Chuchillo Grande, a granite ridge extending from a little west of Maldonada, through Nico Perez to Melo, and at least as far west as the valley of the

Rio Vi (Yi). The deposits on the side of the Chuchillo Grande are conglomerates, arkoses, sands and clay shales, evidently the bordering deposits of the southern side of the basin, formed by the degradation of the granite ridge. He shows that the same formations with local variations in the character of the bedding and nature of the material, occur within this basin, as in Southern Brazil. His arrangement of the beds and correlation with other deposits are shown in the table on page 181. He says that at Fraili Muerto there are beds of glacial boulders, scratched and planed, the undoubted equivalent of the Orleans conglomerate. Near Melo and between Zapucay and Tacuarembó there are great quantities of silicified wood identified as *Dadoxylon.* Guillemain considers that most of the occurrences of this material are the result of transportation by water and not accumulations in the original place of deposition. On the northern border of the Republic, north and west of Melo, at small places called Campo Menasse, and Canãdo d. l. Burros, there is exposed a bone bed, partly in the limestone and partly in the shale, which is made up of the remains of an animal closely related to *Mesosaurus brasiliensis*; as no skulls have been found it is impossible to identify the animal exactly, but the relationship is undoubtedly very close. In beds of similar age near Fraili Muerto there are ripple-marks and innumerable tracks which have been attributed, with some doubt, to Myriapod-like forms.

It is apparent that Guillemain considers northern and central Uruguay to have been covered by a southern extension of the basin of deposition which covered much of southern Brazil. This basin terminated on the south and east where the shore debris from the Chuchillo Grande replaces the normal sediments of the more open water. Toward the west the basin has been traced as far as the Rio Vi (Yi), in the south, and to Tacurembó farther north. The higher beds are in evidence in the western part of the whole area and the lower beds in the eastern part.

Walther (1919) gives a description of the geology of Uruguay, so far as it is known, with a bibliography of 103 titles. He recognizes the same formations as are listed by I. C. White for southern Brazil. His account of the geology agrees in the main with that of Guillemain but he argues against the glacial character of the conglomerates at Paso de Tia Lucia, suggesting that they are rather water-laid boulders and pebbles of other origin than glacial. He admits the glacial character of the, perhaps, equivalent beds in Brazil and suggests the presence of local glaciers on the upland on the Atlantic side of the Permian Basin of South America. He shows that the carbonaceous beds of Rio Bonito and Palermo extend from southern Brazil into Uruguay, but while they may extend to the southern limit of the Permian in Uruguay they are discontinuous, the beds revealed at Boa Vista and Canãda d. l. Burros not appearing at Melo.

The Iraty beds of Brazil are dominantly variegated clays, the line between them and the Rio Bonito beds being taken as at the point where the formations become dominantly sandy. The few outcrops are near Tacuarembó, especially in the Arroya d. l. Burros, and near Paso d. M. Isabel and Passo d. Santiago near Melo.

The Rocinha limestone is not a definite horizon in Uruguay, but appears as lenses and distinct masses. Near Tacuarembó (Passo d. l. Novellos) plants of the *Glossopteris* flora have been recovered, and near the junction of the Tacuarembó and Caraguata Rivers isolated bones and fragments, possibly referable to *Mesosaurus*, occur in a dirty gray, fetid, dolomite (dolomita sapropelitica de color gris sucia). The same beds carry silicified wood of allochthonous origin as a guide fossil. Similar silicified wood is found at Melo and Fraili Muerto.

Walther's paper is accompanied by a map showing the extent of the Permian and Permo-carboniferous deposits in Uruguay and the localities where the Iraty Black Shale is known to be exposed.

Permo-Carboniferous in the Argentine Republic

In northwestern Argentine, in the Ante-Cordillera and the Pampean Andes (Sierra Cordoba, Sierra Famatina, and Sierra San Luis, on the Rio Jackal, and in Guandacol) a series of conglomerates, sandstones and shales overlies the Devonian and Silurian limestone (Bodenbender, 1896). Near Trapiche (region of Guandacol) a gray sandstone, gradually changing to red, overlies the Silurian; this sandstone contains a small patch of coal beds with remains of *Lepidodendron cf. Lepidophloios larcinus* Sternb. and *Neuropteridium validum* Feistm. At Guandacol there is a similar bed lying between the red sandstone above and a graywacke with platy limestone (Devonian?) below. On the Sierra Famatina there is the same sequence of coal beds passing upward into a red sandstone. At Reteamilo, between San Juan and Mendoza there is a series of sandstones, clay shales and conglomerates, including a coal layer. Below the sandstone with the coal bed, the conglomerate has large fragments mostly rounded but some angular; it is reported to be similar in appearance to the Talchir of India. This series is considered to be of Culm age because of the contained plants, as—

Archaeocalamites radiatus (Brgn.) Stur.
Lepidodendron sp. Group of L. nothum Strnb.
    pedroanum (Carr) Szanjocha.
Botrychispis weissia Kurtz.
Rachopteris sp.
Cordaites sp.

Bodenbender considers the presence of this flora as indicating that all of the coal beds and associated beds can not be considered as Permian in age.

In the Pampean Sierras (S. d. l. Huerta, S. d. l. Llanos, S. d. Cordoba) the basal Archean is overlain unconformably by gray conglomerate and arkose sandstone which contains a flora equivalent to the flora of the Karharbari horizon in India. This is followed by a red sandstone similar in appearance to the "Buntsandstein." Similar conditions occur on the east and west sides of the S. Famatina.

Disturbances at the end of the Devonian left a depression in which accumulated, first a mass of conglomerate, not demonstrated to be glacial, and finally sandstone and clay shale in which are seams of coal; all were covered by the Triassic sediments completing a series which is terrestrial throughout.

Keidle (1922) observed in the Pre-Cordilleras two glacial or fluvioglacial horizons separated by carbonaceous shale and sandstone and overlain by sandstone and carbonaceous shale with *Glossopteris* and *Gangmopteris*. The shales and sandstones were correlated by Keidel with the Talchir and the Ecca, and the plant-bearing beds with the Karharbari. Other places in the pre-Cordillera and Pampean Andes can be correlated in the same way. According to Gerth all this speaks for the integrity of Gondwanaland.

In other places Keidel found two marine intercalations with fossils; the older with *Euomphalos* and *Pleurotomaria*, and the younger with Spirifers. These are, according to Keidel, comparable to the marine intercalations in Australia and Tasmania.

In late Paleozoic there was an older landmass and the beginnings of a bordering range which ran at first north-south and then bent toward the east as in the younger cordillera. In S. d. l. Ventana the Permian glacial beds are infolded or included in overthrusts, and in the pre-Cordilleras the Permian is included in repeated layers due to the movement. In other places the Permian ground morain lies on smoothed and striated surfaces.

In eastern Argentina, Permo-Triassic is reported from the region Misiones between the Paraná and Uruguay Rivers, covered by and interbedded with melaphyr flows. This, the São Benito sandstone and questionable deposits in the Province of Buenos Aires have been tentatively referred to the same horizon.

Paraguay

A specimen of *Stereosternum* is figured by Frech in the *Lethea Geognostica* and described as coming from a red sandstone near Villa Rica, Paraguay. No other reference has been found to this occurrence.

Falkland Islands

The original extension of the terrestrial beds to the east and south of their present exposure in South America is shown by their occurrence in the Falkland Islands. The sequence given by Reed (1921) is—

> Slates and sandstones with a typical lower Gondwana flora. The character of the beds indicates rapid seasonal changes.
>
> Glacial boulder bed or tillite, having a mudstone matrix with striated and facetted blocks.

Seward and Walton (1922, 1923) suggest the correlation of the plant-bearing beds with the Ecca and the Talchir, but note that some of the forms, as *Neocalamites carreri* Zeiller, occur in the Rhaetic and suggests that a portion of the beds may be homotaxially equivalent to the Triassic.

CHAPTER XIII

ANALYSIS OF THE FAUNAS AND ENVIRONMENTS

In common with every worker in vertebrate paleontology, the author has had frequent occasion to deplore the necessity which compels the founding of new species and even larger groups, upon imperfectly preserved and incomplete material. In common with every worker, he has openly or tacitly admitted that the giving of a species name is frequently for the purpose of identifying a single specimen which has peculiarities that it is desirable to record and to discuss. Whether such peculiarities be true specific characters, individual peculiarities, accidents of fossilization, or misinterpretations of imperfect or poorly prepared material, is frequently a very open question. This fact is emphasized by the frequent revisions of groups and the frequent references of a single specimen to different groups. No more striking example of this can be found than in the case of the Permian reptile, *Paleohatteria*, which was placed in the Proganosauria by Baur, in the Rhyncocephalia by Credner and Abel, in the Theromorpha by Williston, in the "Anhang" to the Ryhncocephalia by Broili (Zittel), in the Pelycosauria (Bolosauridae ?) by Watson, in the Dromosauria by Nopsca and with question by Watson, and in the Therocephalia by Huene—six ordinal references for one of the best known and most thoroughly studied of the specimens from the Permian beds of Germany. This case might be duplicated many times and is enough to make the paleontologist pause before he draws far-reaching conclusions based upon the material at his command, especially for such remote periods as the Permian

For the reasons given above and for the further reason that there are relatively few specimens from different localities referred to the same species, the author has confined the following lists to an enumeration of the genera and higher groups, and has based such conclusions as he has reached upon that evidence.

For reasons which the author has stated and defended elsewhere and which seem to him to be strengthened by the faunistic and distributional studies described in this paper, he is convinced that the North American-European and the South African faunas (the Permian tetrapods of Russia and Scotland are considered to belong to the South African fauna) had no genetic relationship other than that involved in a very remote common ancestry, and that to unite certain members of the two faunas in a single group, the Theromora, is erroneous. By Permian time these forms were so definitely and irrevocably committed to separate paths of evolution and to distinct fates that they can not, in the opinion of the author, be profitably compared or treated as related.

The growing appreciation of the necessity of studying the environment of the various groups and their adaptation to their environment, as an essential element in their classification, is clearly revealed in the writings of Dacqué, Walther, Abel, Huene, Watson, and others. It is but a part of the growing appreciation of the still more important fact that, in understanding the main phylogenetic lines, it is necessary to disregard the obscuring effects of local adaptation (in both time and place) to the environment, and to base conclusions on the fundamental and persistent morphological advances, alone. The paleobiologist can no longer be patient with new classifications which are simply new mosaics of characters which appeal to the reason of the proposer, even though they be adorned with a wealth of new-coined names.

The thirteen classifications of the fossil reptilia now before us are valuable as representing the views of authoritative workers, but their very number and diversity of grouping show how unsatisfactory is the state of our knowledge. A rational classification can be formulated only when we have succeeded in isolating the fundamental and persistent evolutionary characters and applying them to the main groups, leaving the purely adaptive characters to be applied in differentiating the smaller groups. This can be done only when long and complete series of genetically related forms are known and when it can be demonstrated what characters are purely adaptive and upon what they depend.

Nothing can be more certain than that changes in the skeletons are end results of processes which had previously affected the nervous system, the physiology and the soft anatomy of the animals. Gregory and his students have made a start toward the understanding of skeletal changes by an attempt to restore the musculature of extinct forms; we have some evidence of the relation of the peculiarities of the brain to the external form and skeleton; Nopsca has dared to speculate upon the effect of endocrine glands in the extinct forms. When it can be shown that such changes are related to the environment of the animal, or independent of it, we shall be able to make some permanent advance toward a classification.

Nothing is better established, amidst all the confusion of the discussions as to method of evolution, than the fact that the environment changes before change appears in the organic forms. Equally well established is the fact that the inorganic environment has changed in a rhythmic manner; the geological cycles, large and small, have been repeated with singular persistence and identity of conditions. This recurrence of very similar inorganic environments has consistently resulted in very similar responses from life; so true is this that it may be said that there has been an almost equally rhythmic recurrence of the inorganic environment.

Admitting as a distinct thing the gradual but persistent advance in the complexity of life forms with the passage of geological time, we may say that the response of life to its environment has been a repetitive process. This is saying no more than that there has been repetition of adaptive radiations from different stages of advancing lines.

There is a second group of repeated characters which are to some extent influenced by the environment but seem to have their origin and impetus in less obvious causes. These are morphological characters which appear in the senility of any group.

I take it that it is these repetitive characters, and only these, which Osborn (1925) has in mind when he says that the paleontologist can prophesy evolution—

> "Thirty-six years of intensive paleontological exploration and research have so clearly and repeatedly revealed how new bio-mechanical species arise that we can safely predict not only what the species is, but also where it is most likely to be found and in what stage of evolution it will be found."

Such adaptive characters should be relegated to the differentiation of minor groups.

LIST OF GENERA OF TETRAPOD FAUNA OF THE PERMIAN AND PERMO-CARBONIFEROUS

Faunal lists of the North American region have been published by the author (1915) and by Williston (1916). Lists of the South African fauna have been published by Broom, Watson, Huene, and Haughton; the last-mentioned author has given us a very complete and up-to-date census of the known forms from the Karroo. These lists are so easily accessible that it seems unnecessary to repeat them. In the following annotated list of the tetrapod fauna of the European region, including Russia and Scotland, many synonyms and names of indeterminate specimens have been omitted. The list as presented represents a very fair concensus among workers on the subject.

- Amphibia.
  - Phyllospondyli.
    - Branchiosauridae.
      - Branchiosaurus (Protriton). Lower to middle Permian of France, Germany and Czechoslovakia.
      - Pelosaurus. Lower Permian of France and Germany.
      - Melanerpeton. Lower Permian of Germany, Czechoslovakia and Moravia.
      - ?Acanthostoma. Lower Permian of Germany. Watson regards its position as uncertain.
  - Lepospondylli.
    - Aistopodidae.
      - Aistopod. Lowest Permian of France.
      - ?Adenoderma. Lower Permian of Czechoslovakia.
      - Dolochosoma. Lower Permian of Czechoslovakia.
      - Ophiderpeton. Lower Permian of Czechoslovakia.
      - ?Paleosiren. Middle Rothliegende of Germany. Large form of uncertain reference.
    - Nectridae.
      - Sauravus. Lowest Permian of France.
      - Ptyonius. Lower Permian of Czechoslovakia.

Amphibia—*Cont.*
Lepospondylli—*Cont.*
Nectridae—*Cont.*
Scinosaurus. Lower Permian of Czechlslovakia.
Urocordylus. Lower Permian of Czechoslovakia.
Hylonomidae.
Hylonomus. Lower Permian of Czechoslovakia, Middle Rothliegende of Germany.
Petrobates. Middle Rothliegende of Germany.
Orthocosta. Lower Permian of Czechoslovakia.
Ricnodon. Lower Permian of Czechoslovakia.
Seeleya. Lower Permian of Czechoslovakia.
Limnerpetidae.
Dendrerpeton. Lower Permian of Czechoslovakia.
Limnerpeton. Lower Permian of Czechoslovakia.
Microbrachidae.
Microbrachis. Lower Permian of Czechoslovakia.

Microbrachidae.
Microbrachis. Lower Permian of Czechoslovakia.

Temnospondyli. The classification of the Temnospondylus amphibia follows very closely that of Watson (1917).
Rachitomi.
Eryopidae.
Onchiodon. Middle Rothliegende of Germany.
Actinodontidae.
Actinodon. Lowest Permian of France.
Sclerocephalus. Lower Permian of western Germany and Czechoslovakia.
Chelydosaurus. Lower Permian of Czechoslovakia.
?Losteophorous. Lower Permian of Germany.
Euchirosaurius. Lower Permian of France.
Dissorophidae.
?Zygosaurus. Middle Permian of Russia. The author regards this reference by Watson as very doubtful. It is the single form common to the South African and North American faunas. It is more likely parallel adaptation than genetic relationship.
Zatrachydae.
Dasyceps. Lower Permian of England.
Archegosauridae.
Archegosaurus. Lower Permian of Germany and ?Kashmir. The author regards Smith-Woodward's reference of the Asiatic specimen as very doubtful. It is an imperfect specimen.
Dwinasauridae.
Dwinasaurus. Upper Rothliegende of Russia.
Incertae sedis.
Cochleosaurus. Lower Permian of Czechoslovakia.
Chalcosaurus. Upper Rothliegende of Russia.
?Sparagmites. Lower Rothliegende of Germany, lower Permian of Czechoslovakia.
Discosaurus. Lower Rothliegende of Germany, lower Permian of Czechoslovakia, ?Russia.
Platyops. Upper Rothliegende of Russia.

- Amphibia—*Cont.*
  - Incertae sedis—*Cont.*
      - Nyrania. Lower Permian of Czechoslovakia. Probably Sclerocephalus.
    - Temnospondyli.
      - Embolomeri.
        - Diplovertebron. Lower Permian Czechoslovakia.
        - Nummulosaurus. Lower Permian Czechoslovakia.
        - Macromerion. Lower Permian Czechoslovakia.
        - ?Gephyrostegus. Lower Permian Czechoslovakia.
        - Loxoma. Permian (?Upper Carboniferous) of England.
- Reptilia.
  - Cotylosauria.
  - Reptilia.
    - Cotylosauria.
      - Diadectidae.
        - ?Diadectid vertebrae. Permian of France.
        - Stephanospondylus. Middle Rothliegende of Germany. Huene and Roemer say very close to American Diadectidae.
      - Pareiasauridae.
        - Pareiasaurus. Upper Rothliegende of Russia.
        - Elginia. Upper Rothliegende of Scotland. A similar stage of adaptive evolution to the Russian form.
      - Seymouridae.
        - Kotlassia. Upper Rothliegende of Russia. Huene would place Parasaurus of the Rothliegende of Germany in this family.
      - ?Captorhinidae.
        - ?Phanerosaurus. Middle Rothliegende of Germany.
        - ?Solenodonosaurus. Lower Permian of Czechoslovakia. Pearson (1924) says this form belongs in the Seymouridae, Huene (1925) says in the (Pantylidae) Pantylosauria.
        - ?Sphenosaurus. Lower Rothliegende of Czechoslovakia.
    - Pelycosauria.
      - Poliosauridae, Theropleuridae.
        - Oxyodon. Lower Permian of England. Huene says this form belongs in the Sphenacodontidae.
      - Ophiacodontidae, Sphenacodontidae.
        - ?Callibrachion. Lowest Permian of France.
        - ?Neosaurus. France, horizon uncertain.
        - ?Stereorhachis. Lowest Permian of France.
        - ?Datheosaurus. Lower Rothliegende of Germany.
        - ?Aphelosaurus. Lowest Permian of France.
        - Pantelosaurus. Lower Permian of Germany.
        - Haptodus. Lowest Permian of France.
        - ?Parasaurus. Zechstein of Germany. Perhaps of cotylosaur.
      - Edaphosauridae.
        - Edaphosaurus (Naosaurus). Lower Rothliegende of Germany, lower Permian of Czechoslovakia.
      - Incertae sedis.
        - Kadaliosaurus. Lower Rothliegende of Germany. Regarded by Williston as very close to Areoscelis of North America.
        - ?Paleohatteria. Lower Rothliegende of Germany. This form has been so variously referred that its position is indeterminate. It is extremely primitive but can hardly be referred to the South African fauna.

Amphibia—*Cont.*
  Protorosauria.
    Protorosauridae.
        Protorosaurus. Zechstein of England and Germany.
        Adelosaurus. Zechstein of England.
        Aphelosaurus. Middle Permian of France.
  Therapsida.
    Dinocephalia.
      Tapinocephalidae.
        Deuterosaurus. Upper Rothliegende of Russia.
      Titanosuchidae.
        ?Rhopalodon. Upper Rothliegende of Russia.
        ?Cliorhizodon. Upper Rothliegende of Russia.
        ?Dinosaurus. Upper Rothliegende of Russia.
    Dicynodontia.
        Gordonia. Upper Rothliegende of Scotland and Russia. Large forms similar to those of the Endothiodon and Cistecephalus zones of South Africa.
        Geikia. Upper Rothliegende of Scotland.
        Dicynodon. Upper Rothliegende of Scotland and Russia.
  Theriodontia.
    Gorgonopsia.
        Inostransevia. Upper Rothliegende of Russia.
    Cynodontia.
        Dwina. Upper Rothliegende of Russia.
    Therocephalia.
        Anna. Upper Rothliegende of Russia.
        ?Dasygnathus. Upper Rothliegende of Scotland. A fragment of a jaw which is indeterminate. May be a Pelycosaur, Cynodont or Therocephalian according to Huene.

There is some doubt about the reference of the forms placed in the Therocephalia and Cynodontia; they are so listed on the authority of Huene.

A comparison of this list with those of the faunas of South Africa and North America will show that there is little community below the rank of family, and that such few forms as are now regarded as identical genera are known from fragmentary material. A better knowledge may very properly place them in distinct genera. The most striking community is seen in the amphibia of North America and Europe; increased knowledge may demonstrate this to be only similar adaptive development, or senile characters. Also, it must be recognized that the amphibia are the direct descendants of the Carboniferous forms which were so homogeneous and so widespread and that the resemblances may be due to direct inheritance of characters which are not yet obscured by adaptive changes.

The study of the fish fauna helps but little in understanding either the larger regions or the separate basins of Europe. So large a proportion of the known forms are from the Zechstein (Küpferschiefer and Zechstein dolomite) that they have little bearing on the distribution or relations of the tetrapod fauna. The occurrence of the Zechstein fishes in intercalated layers at certain places helps to date the beds, as in the deposits on the slopes of the Urals.

Unfortunately there is no means by which the fresh-water, brackish-water or salt-water habitat of a fish can be told from the morphology of the skeleton, and the investigator is left rather to gather information concerning the habits of the fish from the enclosing beds and associated fossils than the reverse; however, this is frequently very baffling. Such forms as the Dipnoi and Crossopterygia, which are everywhere found in fresh-water deposits, are pretty widely distributed in the European and North American regions. In general the occurrence of the typical Zechstein fish fauna is in close agreement with the distribution of the Zechstein beds, but there are puzzling associations, both within the limits of the Zechstein Sea and beyond its limits. The Platysomidae would be interpreted as typical reef fish, but they occur in purely fresh-water beds in Texas. The Paleoniscidae were seemingly closely associated with the waters of the Zechstein Sea but there is a reported occurrence in the Döhlen Basin. *Acanthodes*, so common on the continent, is apparently absent from England; *Amblypterus* is also apparently absent from England but the uncertainty of the distinction between this genus and *Paleoniscus* makes the point less valuable. It is possible that certain species of the genus *Amblypterus* were adjusted to fresh water and others to salt water; this is rendered the more probable by the fact that of 24 species from the Lower Permian of France, 15 are unique to the region, 4 are uncertain in reference, and 5 are common to France and Germany. The basins of France are further characterized by the absence of the genera *Gyrolepsis*, *Coelacanthus*, *Platysomus* (?), *Janassa*, and *Wodnikia*.

It has been assumed by Grabau (1921) that the fish of the Zechstein (Küpferschiefer) were largely fresh-water forms and that they were killed by the salt water of the Zechstein Sea flooding the river courses and rendering the waters at first stagnant and finally salt. This seems less probable, as the basins beyond the reach of the Zechstein advance are devoid of this fauna or with only a few specimens. Moreover, the presence of such marine invertebrates as *Stropholosia*, Asteroids, and Foraminifera in the Küpferschiefer show its marine character.

Any attempt to make a critical estimate of the geography or ecology of the time and place on the basis of the fish fauna is largely negatived by the confusion of the taxonomy, but the following annotated list will show the present status of our knowledge.

- Pisces.
  - Elasmobranchii.
    - Acanthodi.
      - Acanthodes. Lower Permian of France, Czechoslovakia and Germany (except the Döhlen basin).
    - Icthyotomi.
      - Pleuracanthus. Zechstein of England, Lower Permian of Czechoslovakia and France, Lebach of Germany, Upper Rothliegende of Russia.

Pisces—*Cont.*
- Selachii.
  - Hybodontidae.
    - Wodnikia. Zechstein of England, Küpferschiefer of Germany.
  - Cochliodontidae.
    - Menaspis. Küpferschiefer of Saal Basin, Germany.
  - Petalodontidae.
    - Janassa. Zechstein of England, Küpferschiefer of Germany.
  - Incertae sedis.
    - Radamas. Küpferschiefer, Saal Basin, Germany. Indeterminate, resembles most closely Squatina an Squaloraja.
- Dipnoi.
  - Ctenodotidae.
    - Sagenodus. Lower Permian of Czechoslovakia and eastern Germany.
    - Ctenodus. Lower Permian of eastern Germany.
    - ?Megapleuron. Lower Permian of France.
  - Phaneropleuridae.
    - ?Conchopoma. Lebach of western Germany.
- Crossopterygii.
  - Coelacanthidae.
    - Coelacanthus. Zechstein of England, Küpferschiefer of Germany, Permo-carboniferous of Madagascar.
  - Osteolepidae.
    - Megalicthys. Lower Permian of Czechoslovakia.

Ganoidei.
- Heterocerci.
  - Paleoniscidae.
    - Acrolepis. Zechstein of England, Upper Rothliegende of Russia, Küpferschiefer of Germany.
    - Amblypterus. Lower Permian of France, Rothliegende of Germany, Upper Rothliegende of Russia.
    - Elonicthys. Lower Permian of Czechoslovakia, Upper Rothliegende of Russia, Lower Rothliegende of France and western Germany.
    - Paleoniscus. Zechstein of England, Upper Permian of France, Küpferschiefer of Germany, Upper Rothliegende of Russia, Upper Permian of Moravia.
    - Pyritocephalus. Lower Permian of Czechoslovakia.
    - Sphaerolepis. Lower Permian of Czechoslovakia.
    - Pygopterus. Zechstein of England, Küpferschiefer of Germany, Permian of France.
  - Platysomidae.
    - Dorypterus. Zechstein of England, Küpferschiefer of Germany.
    - Ecrinosemus. Permo-carboniferous of Madagascar.
    - Globulodus. Zechstein of England, Küpferschiefer of Germany.
    - Platysomus. Zechstein of England, Küpferschiefer of Germany, Upper Rothliegende of Russia.
- Orthoganoidei.
  - Stylodontidae.
    - Acentrophorous. Zechstein of England.

In addition to the tetrapod and fish fauna there are many footprints known from England and the continent. Nopsca (1923) has listed many and has attempted to assign them to different groups. While the author is in full sympathy with Nopsca's attempt, he believes with Huene that these footprints can only be used to advantage when better understood.

Any listing or discussion of the air-breathing invertebrates has been omitted because so far as we know their history and distribution throw no light upon the development or distribution of the tetrapods.

A review of the preceding summary descriptions of the beds and discussion of the faunas, with the comprehensive pictures of the South African area by Watson (1914), Abel (1922) and Huene (1925,[1], 1925[2]) and the picture of North America by the author (1915, 1919), will demonstrate pretty conclusively that there were three areas where the Permian tetrapod life developed independently, probably from a more or less common Carboniferous ancestry. Intermigration between North America and Europe was apparently possible but not an easy route for the tetrapods; intermigration between the South African region and its extension into the Northern Hemisphere, and the other two regions was, apparently, entirely prevented.

The inorganic environment of each of these three areas was different from the others; there was but a single common factor, the progressive increase in aridity which terminated in desert, or semi-desert, conditions.

South Africa was a great aggradational area devoid of physiographic or hydrographic features which could limit or guide the development of the fauna in the early part of Karroo time, but possessing a more diverse environment in the latter part.

North America, except in the extreme eastern part which was more like central Europe, was a region of lagoons, swamps, and river-flood plains, bordering the sea; diversity of land features and rigor of climate caused concentration of the life in favorable localities and furnished an abundant variety of life conditions.

Central Europe was, in early Permian time, a region of isolated basins occupied by a relict Carboniferous fauna. The basins were dominated and separated by prominent physiographic barriers; during the development of Permian time the area of the basins was increased and the area of sedimentation was increased at the expense of the barriers, until there was a complete union of many of the originally isolated basins. Finally a part of the area was invaded by the Zechstein Sea.

The evidence of the trend lines of the Hercynian uplift, of the distribution of the flora, of the fresh-water fish fauna and of the tetrapod fauna shows that there was a land connection between North America and Europe in early Permian time, if not through all Permian. That the migration route was not an easy one is indicated by the relatively small numbers of the American forms which found their way into Europe. So striking is this fact that it led Williston (1909) to say—

> "The fauna (of North America) was literally *sui generis* and I may almost say *sui ordinaris*. But two or three genera of the two types out of the scores of genera known can be correlated as showing resemblances—family resemblances I mean—with foreign forms."

This statement needs but little modification today, a few more forms common to the two regions have been found. The European flora readily found its way to North America, a fact which renders the nature of the barrier to the movement of tetrapod life very difficult to understand. Ordinal community is much better established if the references based upon fragmentary and incomplete material are accepted, but it is more in consonance with the history of paleontology—that when the specimens now indicated by fragmentary jaws and isolated bones are better known, they will be placed in new and remote groups. It may very well be established that what now appear as evidences of identity are merely similarities due to parallel development under similar conditions of environment.

The South African fauna more nearly realizes the sense of Williston's remarks; wherever it is found it is the same and unmixed with other faunas. The few exceptions noted by various writers are too uncertain in identification and too little supported by other evidence to be accepted, as yet. Riabinin's (1915) reference of a specimen from the Urals to *Edaphosaurus* (*Naosaurus*) is based upon a fragment of the anterior end of a jaw which to the author does not appear to warrant the reference; Huene's (1925) reference of *Paleohatteria* to the Therocephalia and Watson's reference of the same specimen to both the ?Bolosauridae and the ?Dromosauria show how uncertain are the determinations. Only *Zygosaurus*, referred by Watson (1917) to the American family Dissorophidae, remains. Watson based his reference on the laterally placed orbits and otic notches, the closure of the otic notch, the deeply cupped occipital surface, and "general build and proportions" of the skull. When one reflects that this is the sole specimen that can be considered as showing a community of the faunas and that the closure of the otic notch is not a unique thing, occurring also in the Stegocephalian *Trematosaurus* according to Williston, one hesitates to accept the family identity of *Cacops* and *Zygosaurus*.

As has been said above, the single common factor in the environment of the faunas of the three regions was the progressive change of climate from humidity to a relatively extreme degree of aridity in the late Permian and Triassic, but this single factor brought in its train a long series of secondary changes which were essentially similar in all the regions. Such secondary changes were decreases in area of aquatic habitat, decrease and change in the vegetation, change in the surface of the land and the character of the soil due to erosion and sedimentation, and many others of similar kind. All such changes tend to force the faunas to concentrate in favorable localities where food and water could be obtained. Such concentration compelled severe competition which, with the increasing rigor of the environment, induced more rapid evolution.

That this succession of environmental changes, so much alike in each region but with peculiarities characteristic of each region, was developed within approximately the same interval of time is indicated by the relation of the terrestrial beds to the marine deposits. Böse (1917) and Beede (1924) have given the last summary accounts of the marine Permian and indicated the correlation of the beds. These papers contain a very full bibliography of the subject. Böse gives the table (see p. 200) based upon the distribution of the ammonoids; it can easily be correlated with the tables of the terrestrial beds in this paper.

Beede's valuable paper (1924) is concerned with a description of the genus *Schwagerina* and related forms, the distribution of the genus, both geologically and geographically, and a demonstration that the appearance of the genus may be taken as marking the inception of Permian time. His analysis of the beds in which *Schwagerina* occurs is accompanied by an attempt to show that the beginnings of the Permian flora and air-breathing vertebrate fauna were contemporaneous with it, "at least homotaxially."

His conclusions are as follows:

> (1) *Schwagerina s. s.* is a well-defined genus whose species are distributed over much of the Northern Hemisphere.
>
> (2) They were pelagic organisms of widest and nearly contemporaneous distribution over the seas of that time.
>
> (3) Schwagerinas occur near the level at which the simpler Fusulinas broke up into diverse forms.
>
> (4) At or near the base of this horizon, the older faunas and floras were greatly reduced and newly developed species and genera appear which come to dominate the later fauna and flora.
>
> (5) Some species of *Schwagerina* persist well up into the Permian rocks, as in the case in the Sicilian and the southern Chinese regions.
>
> (6) *Schwagerina* forms a good index fossil and its earlier occurrences may safely be taken as the base of the Permian deposits.
>
> (7) This interpretation (No. 6) is not seriously out of harmony with similar correlation lines laid down on the basis of other organic remains.

While the world-wide climatic change was demonstrably within the Permo-carboniferous and Permian, it was not synchronous in action in all places and the effect upon the faunas was certainly not synchronous. I. C. White long ago insisted upon the early appearance of red beds in the Carboniferous of eastern North America as indicating the beginning of Permian conditions and the author has attempted to prove the progressive character of the change, both in time and place for the North American continent (1919); the French geologists have shown the same kind of a progressive movement in the Central Plateau, and Hennig has insisted upon it for the Schwarzwald and the German region. A similar progressive change is shown in the history of the migration of the South African fauna and the associated *Glossopteris* flora from the Southern to the Northern Hemisphere.

This succession of changes guided the development of the tetrapod fauna

Approximate Correlation of the Ammonoid-bearing beds of the Permo-Carboniferous and the Permian.

		North America.				Eurasiatic Mediterranean Region.	Urals.	Central Asia.	Himalayas.	Salt Range of India.			Island of Timor.
		Glass Mts.	Shafter region.	Guadaloupe Mts.	Central Texas.								
Overlying Beds.		Cretaceous.	Cretaceous.		Triassic Red Beds.	Lower Triassic.				Ceratite Beds.	Lower Triassic.		
Permian or Dyas.	Thuringian.					Bellerophon limestone of Alps. Hungarites, Otoceras Beds of Djulfa, Armenia.	Brackish and Inland Sea Deposits.			Zone of Episagiceras wynwei. Zone of Cyclolobus oldhami.	Chideru Group.	Upper Productus Limestone.	Cyclolobus Beds of Ajer Mati.
	Saxonian.	Unconformity.			Red beds.			Karakorum Pass. Cephalopod beds. of Woabjilga.	Chitichun limestone. Kuling shale of Spiti.	Zone of Zenaspis carbonaria.	Virgal Group.	Middle Productus limestone.	
	Permo-carboniferous. Upper.	Gilliam.											
		Vidrio.	Unconformity										
			Yellow limestone.	Capitan limestone.					Productus shale of Lilinthi.				
		Zone of Waagenoceras (Word).	Zone of Dalmatites (thinbedded).	Zone of Waagenoceras (Delaware beds).	Double Mt. Division.	St. Girons Beds (Pyrenees) Sosio Beds (Sicily) Mrzla-Vodica Beds (Croatia)	Kungur Beds (Upper Arta Beds).				Amb Group.	Lower-Productus limestone.	Cephalopod beds of Bitanu.
		Zone of Perrinites (Leonard).	Zone of Perrinites (brecciated).		Zone of Perrinites Clear Fork D.		Cephalopod bearing ss. (Lower Arta Beds)	Cephalopod bearing beds of Darwas (Bokhara).		No Ammonoids known.	Warcha Group. Dandote Group. Talchir Group.	Middle and Lower Speckled Sandstone.	
	Permo-carboniferous. Lower.	Zone of Prothallassoceras (Hess limestone and cong.)	Transition Beds.	Hueco Beds.	Albany Wichita Division.	Trogofel beds Carnian Alps							
		Unconformity.											
		Zone of Uddenites (Wolf Camp).	Yellow limestone.				Unconformity.			Unconformity.			
		Cisco. Highest Carboniferous.	Shales. Cieneguita (Up. Carb.).	?	Cisco Beds. Uppermost Carboniferous.	Schwagerina beds. Auernig beds. Uppermost Carboniferous.	Schwagerina beds. Cora beds.	Uralian.	Barus beds of Kashmir.	Cambrian.			

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of Carboniferous age which was essentially similar in Northern America and Europe, and, presumably, was widely spread in the Southern Hemisphere, though one is inclined to suspect that there was less community of forms between the two hemispheres; evidence is lacking upon this last point.

Because of initial or essential differences in the three regions the series of progressive environmental changes acted upon the original (Carboniferous) faunas in a manner sufficiently different to produce radically different faunas by Permian time. Because of greater initial similarity or because of the possibility of intermigration, the faunas of the two northern regions resemble each other more than they do the fauna of the southern region.

It is commonly assumed that the places of most abundant and varied life were centers of distribution; far too frequently it is also assumed that such places were centers of origin. The latter assumption does not necessarily follow from the former and is a frequent source of error. The eccentric pressure from such a region of abundant population was one of the effective causes of migration.

The great barrier to intermigration between the southern and northern regions was the mediterranean Tethys; this was crossed at only one, seemingly well-indicated, place. The floras of the two hemispheres met and mingled and the faunas approached each other only after long and devious wandering of the southern forms. The South African fauna was, apparently, exerting a strong eccentric pressure in the Permian, which was only equaled by that of the *Glossopteris* flora. The movements of the two were so similar that they may well be considered together.

Glacial conditions developed in the Southern Hemisphere in late Carboniferous time. The *Glossopteris* flora is present in interglacial deposits in Australia and closely follows the glacial stage in Africa; from these regions it spread northward, appearing in Russia in late Rothliegende or early Küpferschiefer time and spread westward through Asia till it left its last traces in the Rhaetic of Indo-China and, perhaps, Mexico.

As has been shown on previous pages, the existence of the time-honored Gondwanaland is based on very slender evidence, other than that of the *Glossopteris* flora. The discovery of this flora on the Falkland Islands and the Antarctic continent suggests another route of its dispersal in the Southern Hemisphere. No traces of tetrapod life referable to the South African fauna have been found in Australia, and it is not likely that such traces will be found. "*Bothriceps*" *huxleyi* of South Africa belongs to the genus *Lydekkerina* and is quite distinct from *Bothriceps australis*. (*Fide* Watson.)

It has been shown that deposits comparable to those of the Karroo can be traced for only a limited distance north and east from the Transvaal-Rhodesian center of dispersal of the ice in Permian time. Huene's (1925) effort to demonstrate a land surface in northern Africa in Permian time and a route of migration across the Iberian Peninsula seems unconvincing in the light of the absence of any trace of the South African fauna along the suggested route, between the northern part of the Karroo and northern Russia. Surely if the tetrapod fauna could have gone that way the *Glossopteris* flora could have accompanied it, and such a dominant flora could not have failed to leave some trace in places which have been so well searched.[1] On the other hand we have evidence of the extension of the South African fauna as far north as Tanga in East Africa, in Madagascar (? *Mesosaurus* and a stegocephalian), and *Dicynodon* in India. The *Glossopteris* flora is found in Madagascar and India; it either spread directly from Australia to India or across the Indian Ocean to South Africa and so north. The first suggestion seems the most reasonable. It has been shown that terrestrial deposits spread far south in the Malay Peninsula and very temporary land connections or narrow seas and currents might have carried the flora where the animals could not go. Moreover, it has been shown that marine fossils occur in West Australia identical with those of India, indicating the presence of an open sea on that side.

By some land in the western Indian Ocean or along an extension of the eastern coast of Africa, the South African fauna might have found its way into India as far as the southern border of the mediterranean Tethys. That the southern fauna and flora could, and did, spread well north in India is shown by the presence of terrestrial beds in Kashmir, the presence of the *Glossopteris* flora, and the presence of a stegocephalian (? *Archegosaurus*) and two species of the fish *Amblypterus* (Seward and Smith-Woodward, 1905). This is certainly the closest observed approach to the barrier from the southern side and the possibility of crossing in this place is made at least plausible by the consideration of certain tectonic features of the region.

The Peninsular portion of India is a positive element made up largely of pre-Paleozoic rocks. On its northern flanks lies the plain of the central India. North of this plain the mountain ranges of Asia bend sharply to the north. Through Baluchistan, Afghanistan and Kashmir the Hindu Kush and the Himalaya Mountains trend northward in a great arc. Hundreds of feet of marine limestone are present in these ranges but in the deformation of the Asiatic continent the mass of rock was bent into a great arc, upon the coign of Peninsular India. The point is, that though this arc is now far to the north of the exposed pre-Paleozoic mass of the peninsula, the mass extends to the north beneath the central plain of India and formerly extended even farther, as is shown by the terrestrial deposits of Kashmir and the Salt Range. Possibly it extended far out into the mediterranean Tethys, narrowing the sea at this point, or forming an archipelago across which the migrations might take place. Once across, the migration could have gone by way of the Khirgiz Steppe to the Donetz Basin and to northern Russia, on the one hand, and to eastern Asia and, perhaps, North America on the other. Grabau's explanation (1923–24, pages 339–340) of the difference between the Asiatic and European marine faunas of the time is of interest in this connection. One has but to consider the relatively recent bridges across the present Mediterranean to find an illustration of the possibility.

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[1] In his recent paper (cited on page 148) Haughton has come to a similar conclusion.

"How are we to account for the presence of a South African Permian fauna in Russia and Scotland and its absence from Central Europe? Any migration must have taken place across the sea of Tethys which, in upper Carboniferous times, stretched from North India, westwards, to the Iberian Peninsula. That South Africa was the centre from which migration of the Permian Karroo fauna began seems undoubted, and migration can easily have proceeded northwards to the southern shores of Tethys. In Permian times Tethys shrank in size, and there was almost undoubtedly an Iberian land-bridge from North Africa to Spain which became submerged in the Triassic. It is across this bridge that von Huene believes the Karroo reptiles spread into Europe; but a strong objection to that theory is the absence of South African forms in the Central European area through which they should have passed on their way to Russia, and the completely North American aspect of the Permian reptiles of Central Europe. Some of these North American forms penetrated into Russia; but it is scarcely conceivable that the abundant Karroo fauna of Russia should not have left some trace of its passage through Central Europe had they taken that route. We must look elsewhere for the Permian passage of Tethys by these migrants, and the conclusion is reached that the road taken passed through Syria and by an isthmus or a chain of islands to the Caucasus or to Persia and thence westwards. East of Russia was land in Permian times; in Persia and in Syria Permian beds are missing and Trias lies unconformably upon marine Upper Carboniferous. Migration from Africa, northwards, through this temporarily diminished part of Tethys would explain the facts of distribution better than the use of the Iberian bridge. Zalesky (quoted by Seward in his Antarctic Paper) also supposes that at the end of the Paleozoic era there was a connection between the opposite shores of Tethys by an isthmus or through a chain of islands."

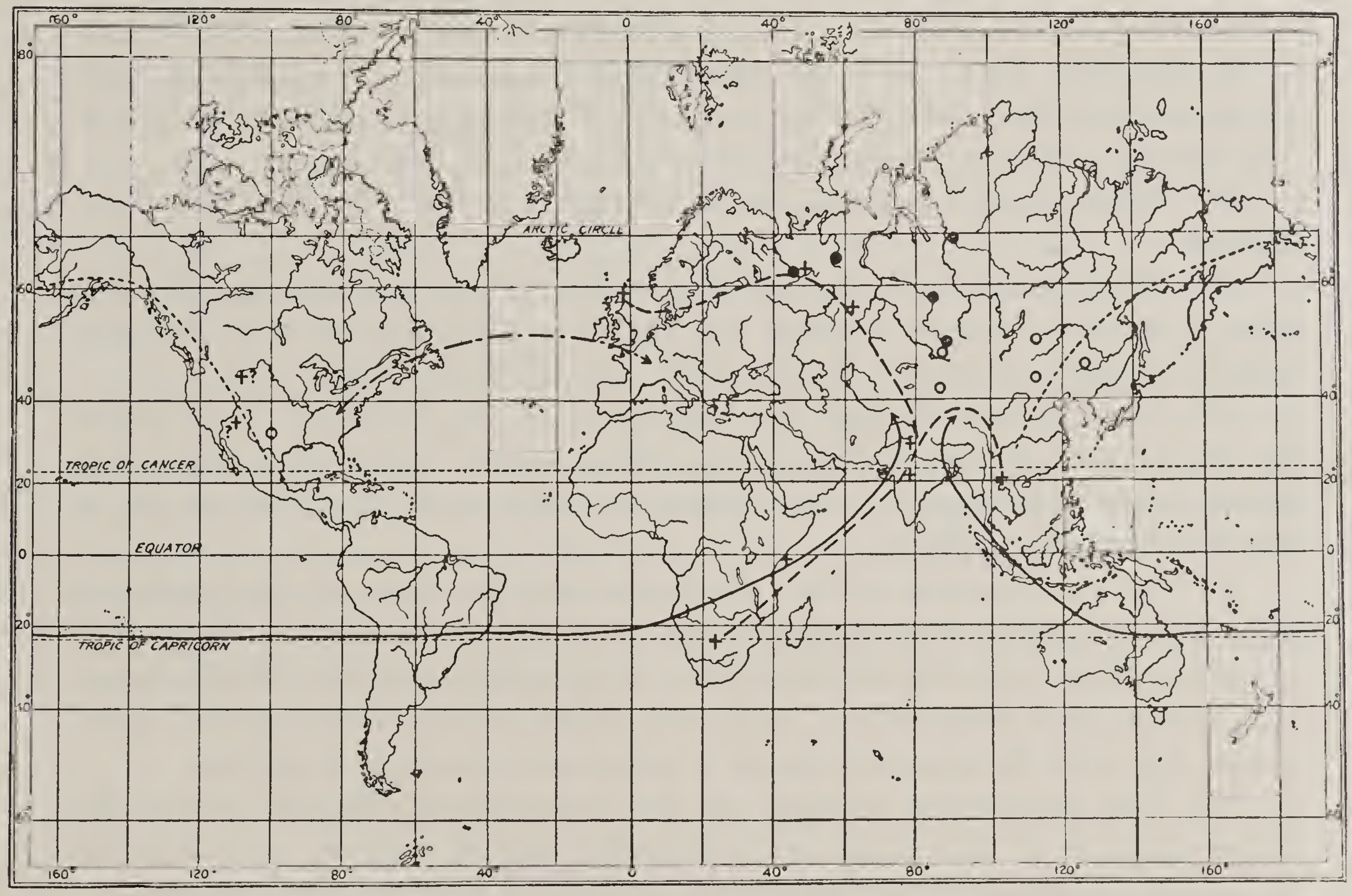

FIG. 23.—Map showing possible movements of *Glossopteris* flora and South African fauna. Solid lines, *Glossopteris* flora; black spots, *Glossopteris* flora and European flora mixed; empty circles, indications of *Glossopteris* flora; dashed line, possible movement of South African fauna; crosses, locations of South African fauna; dot and dash line, intermigration of North American and European faunas and floras; dotted line, possible route of migration of South African fauna and *Gigantopteris* flora from Asia into North America.

The accompanying map, slightly modified, from Gothan (1911) shows the migration and distribution of the *Glossopteris* flora and the possible movements of the tetrapod fauna.

The same process of reasoning permits an explanation of the presence of ? *Dicynodon* in the Triassic of Indo-China and the presence of ? Dicynodonts and ? Dinocephalians in the Triassic of North America. (*Dolicobrachium*, *Eubrachisaurus*, *Brachybrachium* from the upper Triassic of Wyoming, and *Placerias* from the upper Triassic of Arizona.) The spread of conditions similar to those of the Southern Hemisphere permitted the fauna and flora to migrate under its eccentric pressure until its last elements appeared in north Russia and Scotland toward the west and as far as Mexico, perhaps (Gothan, 1911), toward the east.

Why so few traces of the South African fauna have been found in eastern Asia and in North America, when they spread so freely toward the west, no suggestion can be offered. Perhaps the unexplored portions of Siberia and Mongolia will yet yield traces of an abundance of forms of which we now know nothing. As for North America, the author has spent many weeks in a careful search of the upper Permian and lower Triassic terrestrial beds of western North America and has very little hope that much will be found.

In bringing this work to a close the author ventures certain conclusions.

I. Any line drawn between the Carboniferous and the Permian must be an artificial line, desirable for purposes of mapping but not indicative of any sudden climatic, diastrophic or biologic change.

II. There must be recognized a transition period, the Permo-carboniferous.

III. There was initiated in late Carboniferous time a progressive climatic change which continued through the Permian and culminated in the very widely spread and intense aridity of the late Permian and Triassic.

IV. The climatic change was signalized in the Southern Hemisphere by the advent, in late Carboniferous time, of the period of refrigeration which culminated in continental glaciation and made its influence felt in the Northern Hemisphere.

V. The environment of life, the fauna and the flora, of Carboniferous time was relatively very homogeneous over the whole world. From that condition there were differentiated three zoogeographic regions, North America, Europe, and South Africa, each with characteristic environmental characters but with the common factor of progressive increase in aridity.

VI. The progressive changes in the environment affected profoundly every element of the biota—so profoundly that it may be said that the initiation of Mesozoic conditions was as early as the late Carboniferous.

VII. The tetrapod fauna of the three regions contained many relict elements from the well-established Carboniferous fauna, but the peculiar environmental factors of each region induced (or permitted) the development of a distinct fauna in each region.

VIII. The European and North American regions were connected in such a way that intermigration was possible but not easy for the tetrapod fauna.

IX. The South African region was extended by the progressive physiographic and climatic changes into the Northern Hemisphere, probably by way of the east coast of Africa, through India, and across the mediterranean Tethys in the region of northern India. It spread to the north and west until it reached northern Russia and Scotland; there is evidence that it spread to the east and even crossed to the continent of North America by late Triassic time.

X. The results of this study do not support the theory of the existence of a great continent in the Southern Hemisphere, Gondwanaland, including in its extent South Africa, South America, and Australia in Permian time. There seems to be good evidence that Australia was isolated from the other two continents.

XI. While the author has no suggestion as to the method of evolution, and has no concrete instances to offer in evidence, he is impelled to record here his conviction that the environment is in some way a fundamental factor in the process. In common with every paleobiologist who has considered evolution in the perspective of time and environment, this conviction is forced upon him[1]. That there are fundamental progressive changes developing independent of the environment through long time, there can be no doubt. That there are series of changes very similar in character, often and consistently repeated, and closely related to synchronously repeated environmental changes, seems equally beyond question. Until the results of the experiments of the neobiologists have stood the test of time, a test which they neglect or sadly undervalue, the author is content to say that, in his opinion, for all adaptive evolutionary changes, the environment either induces the result or acts as the selective screen which determines what forms shall survive and what perish; the environment determines what path life shall take. Whether this statement applies to the major and fundamental changes which have separated the higher groups, even the paleontologist has not as yet the grasp of the effect of time and cosmic environmental changes to venture an opinion.

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[1] In this connection see an article by Nopsca, *Heredity and Evolution*, Proceedings Zoological Society of London, Part 2, 633-665, July, 1926.

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